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CRITICAL EXAMINATION

OF

THE FIRST PRINCIPLES

OF

GEOLOGY;

IN

A SERIES OF ESSAYS.

By G. B. GREENOUGH,

PRESIDENT OF THE GEOLOGICAL SOCIETY,

F.R.S. F.L.S.

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PREFACE.

THE object of the following work is too clearly stated in the title page to require explanation. In furtherance of that object I have sometimes felt myself called upon to criticize the opinions of other writers. On those occasions I have done so with freedom, but I trust also without offence; for it were absurd to suppose that I do not feel respect for the intellectual and moral character of many persons, whose ideas on abstruse and speculative questions are at variance with mine. Errors emanating from men of acknowledged merit most require exposure, because they are the most contagious.

It should be recollected also, that many of the opinions here combated were ad-

vanced at a period when much less was known than is known at present, and would now, perhaps, if opportunity offered, be disclaimed even by their authors. I make this observation not in candour merely, but in prudence; being satisfied that, if geological science continues to advance at the rate it has done lately, the essays now submitted to the public will, before many years have elapsed, be found to contain as many errors as they presume to correct.

CONTENTS.

ESSAY I.	*On Stratification.* - -	Page 1
II.	*On the Figure of the Earth.* -	91
III.	*On the Inequalities which existed on the Surface of the Earth previously to diluvian Action, and on the Causes of these Inequalities.* -	200
IV.	*On Formations.* - -	214
V.	*On the Order of Succession in Rocks.*	231
VI.	*On the Properties of Rocks, as connected with their respective Ages.*	260
VII.	*On the History of Strata, as deduced from their Fossil Contents.* -	296
VIII.	*On Mineral Veins.* - -	306

ESSAYS

ON THE

ELEMENTS OF GEOLOGY.

ESSAY I.

ON STRATIFICATION.

STRATUM is a word so familiar to our ears that it requires some degree of manliness to acknowledge ourselves ignorant of its meaning: the sense in which it is used is, however, very far from being precise. Easy as it may seem to determine whether a given mass be, or be not stratified, there is, perhaps, in the whole range of geological investigation, no subject more pregnant with controversy.

By way of illustration, I ask, whether granite is stratified?

"It is stratified, certainly," says [a] Gruber, "in the Riesengebirge; but do not pin "your faith on authority; take the evi- "dence of your senses; consult your eyes; "look at the rocks on the banks of the "Elbe, the Schneegrube, the Alpengrube, "the Schneekoppe; stratification is so "evident at all these places that no man "in his senses can doubt it."

"It is no less evident," says [b] Charpentier, "at the drey Steinen: and again at "Morgenstern," says Professor [c] Schubert, "at St. Gunther, at the Rathhausberg in "the forest of Bohemia, at Toplitz, at "Carlsbad."

"I can vouch for its stratification at Carls- "bad," says Deluc [d], "and if you want other "localities, you may add, on my authority,

[a] Gruber's Riesengebirge, p. 189.

[b] Beytrag zur Geogn. Kentniss. des Riesengeberges, p. 32. [c] Geognosie, p. 119.

[d] Travels in France, Switzerland, and Germany, § 506, § 525, § 549, § 743, &c. &c.

" Grosse Rad, Friesenstein, and the valleys
" of the Zackel and the Queis."

But why so particular?

" It is stratified," says Dr. [a] Mitchell,
" along the chain of the Riesengebirge for
" fifty miles together." " For one hundred
" and fifty," says Professor Jameson.[b]

Yet M. von Buch [c] followed this chain for nearly a hundred miles without being able to discern, in any part of it, the slightest trace of stratification.

Let us go from the Riesen to the Erzgebirge.

" You will surely admit," says Professor Schubert[d], " the granite at Johan-Georgen-
" stadt and Schwarzenberg to be stratified.
" M. von Buch[e] will not admit it."

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[a] Scottish Isles, p. 37.
[b] Nicholson's Journal, vol. ii. p. 227.
[c] Journ. de Physique, vol. xlix. p. 211.
[d] Geognosie, p. 119
[e] Journ. de Physique vol. xlix. p. 211.

But the Fichtelgebirge.

The stratification of granite at the Ochsenkopf[a] is recorded by M. de Luc. Mr. Buckland, Mr. Wm. Conybeare, and myself looked for stratification there, but in vain.

Saussuré imagined, for some time, that Mont Blanc[b] was unstratified, but at length corrected his opinion. The mistake arose from its strata being of a thickness so enormous, that there are few points of view from which they are visible.

M. von Buch[c] says, that the granite of Mont Blanc is distinctly stratified; that the strata are vertical, or dip very gently to N. having the same direction as the chain.

M. Brochant affirms, that in the high Alps, granite is at times stratified, and that very decidedly. Gastern[d], in the neighbourhood of Salzburg, is cited by Schubert as affording stratified granite. At Pommat,

[a] Travels, vol. ii. p. 503.

[b] Voyages aux Alpes, § 919.

[c] Uber die Ursacken der Verbreitung grosser Alpengeschiebe in Tr. of R. A. of Berlin. 1815.

[d] Geogn. p. 119.

according to Ebel[a], the peasants slate their houses with it. At St. Roch[b], a hill on the Italian side of the Alps, Saussure tells us, "that there are eight distinct beds of "granite, the bottom one sixty feet thick, "the next fifty, the third twenty, the re- "maining five, forty, twenty-four, forty, "ten, forty. The lowest contains a half- "inch stratum of white feldspar, which is "parallel to the other strata. Similar "appearances present themselves between "Cresciano and Giornico."

Messrs. Brieslak and Isembardi[c] could discover no stratification in the granite north of Lario, and von Buch[d] denies that it is ever stratified in the Alps. "The "whole rock," he says, "is an assemblage "of crystals, united by the force of crystal- "lization," which was the opinion also of La Metherie.

Schubert[e] affirms, that granite is stratified in the Pyrenees. Cordier[f] admits this,

[a] Manuel. Pommat.
[b] Voyages aux Alpes, § 1752, § 1798.
[c] Brieslak's Geol. p. 156.
[d] Journal de Physique, vol. xlix. p. 211.
[e] Geogn. p. 119. [f] Journal des Mines, vol. xvi.

adding, "that the strata exhibit no regularity of direction:" "such is precisely "the case," says Dolomieu[a], "of all the "granite which has fallen under my ob- "servation."

To come nearer home.—Professor Jameson[b] states, that the stratification is very distinct at Goatfield, the principal mountain in the Isle of Arran: Professor Playfair[c] is of the contrary opinion.

Professor Playfair[d] admits, that the granite of Mount Sorrel is stratified, not however without considerable hesitation, as his companion, Lord Webb Seymour, does not concur with him.

In the bed of the Ockment[e], in Devonshire, granite lies in slabs like lias.

M. de Luc[f] found stratification very evident in Cornwall at St. Columb, Tregonning Hill, the Land's End, Castle Trereen; and Mr. Conybeare at Cliggar. At St. Just the

[a] Journ. de Physique. [b] Scottish Isles, p. 27 & 35.
[c] Illustrations, p. 329.
[d] Illustrations, p. 328.
[e] Geol. Trans. vol. iv. p. 402.
[f] Travels in England, § 1120, § 1168, § 1181, § 1189.

granite rises in large flag-stones. At St. Michael's Mount it exhibits parallel planes separated by layers, or wayboards of quartz. At Carglaze the parallelism is strikingly regular.

Dr. Berger, however, did not find granite stratified in Devonshire or Cornwall; nor has he found it so in any part of the Continent.

Dr. Hutton could never observe any regular structure in granite except that of divisions to which the shrinking of the mass gave rise after its consolidation.

Humboldt[a] discerns every where, in granite, strata, which in all parts of the world have the same dip and direction.

In one passage of Bergman's[b] works, mention is made of granite stratified horizontally. In another, the author says, "I "cannot allow any granite to be stratified "till it shall be found incumbent upon "some other rock."

---

[a] Journ. de Physique, vol. liii. p. 46.

[b] Geog. Physique, vol. i. Bergman.

Few authors[a] have expressed their opinion on the subject of syenite, porphyry, hornblend rock, greenstone, serpentine, primitive and transition limestone, siliceous slate, greywacke; but the stratification of these and other substances is no less ambiguous than that of granite. M. de Luc, for a long time denied, that any of the primitive, or as he calls them, primordial rocks were to be found stratified. This opinion was afterwards renounced by him[b], but still found a supporter in la Metherie.[c]

The term flötz-rocks was originally, I believe, employed upon the supposition that in them only was stratification observable, a supposition which is doubly erroneous, a stratiform structure, in whatever sense that phrase is used, being neither peculiar to flötz-rocks nor essential to them. Trap, a substance which derived its name from the circumstance of its occurring in successive steps, or terraces, piled one above another,

[a] Jameson's Geol. and J. des M. vol. xxvi. p. 173.

[b] Journ. de Physique, vol. xxxviii. p. 372.

[c] Theorie de la Terre, vol. iv. p. 352.

is denied, by Huttonian writers, all claim to the title of stratiform.

Whence this contrariety of opinion? Are our senses at variance, or our judgments? The cause I think is obvious. Every one uses the word stratum, no one enquires its meaning; the remedy is as obvious — definition.

Let us pass in review the several appearances in which this confusion has originated.

1st. Some rocks present external planes parallel to each other, but are not subdivided by internal planes.

Stratum is a literal translation of the word bed, and most writers use one or other of these expressions indifferently. Professor Jameson[a] not considering how injudicious it is to employ synonymes for the purpose of expressing contrast, has

[a] Geology, p. 51.

introduced a distinction between them. Similar contiguous masses are by him denominated strata, dissimilar ones beds.

Mr. Martin[a] has protested against this innovation, and few authors without the Wernerian pale appear disposed to adopt it. Those who feel the value of such a distinction, will do well, therefore, to select some happier phrase to express it.

2d. Parallel internal planes are not always co-extensive with the rock in which they occur. Professor Jameson[b] observes, that "the seams of the strata, or those lines "which are said, in all cases, to mark the "boundaries of a stratum, do not always "continue throughout the whole mountain "range." Brieslak[c] affirms, that, "the "strata of flötz rocks are often false, con-"fined to the surface, an effect of decom-"position; so that on one side you see "them disposed in one direction, on the "other, in a contrary direction. Attempt-

[a] Outlines, p. 170.

[b] Mem. of the Wern. Soc. vol. ii. pt. i. p. 222.

[c] Brieslak's Introd. à la Geologie, p. 233.

" ing to follow what seemed to be the part-
" ings of strata, he has found repeatedly,
" that it was impossible to do so to any
" distance." Dr. Pacard remarks[a], that,
" what appear to be beds, particularly in
" mountainous tracts, are often not so in
" reality, the appearance being given by
" fissures, veins, furrows, zones, folds, &c.;
" that the interior of rocks is often very
" different from their exterior; that he has
" seen these lines more or less superficial,
" suddenly stopped by a large block; that
" the quarry-men often find zones, veins,
" &c. die away as they advance in the ex-
" cavation." Townson[b], speaking of some rocks which he examined in Hungary, says,
" they were formed of one bed of compact
" limestone, about twenty-six yards thick.
" In one place it was pretty regularly divid-
" ed into four or five beds; but these divi-
" sions, or signs of stratification, only ex-
" tended a few yards: between these beds
" were four or five thin beds of black silex
" running parallel to each other, but these

[a] Journ. de Physique, vol. xviii. p. 185.
[b] Townson's Travels in Hungary, p. 349.

" likewise were only of a few yards extent,
" and sometimes interrupted by the lime-
" stone."

" In some places," says Williams[a], " the
" mountain limestone appears regularly
" stratified, in others, one vast irregular bed
" of very unequal thickness."

3d. Parallel planes are sometimes too distant from each other, at other times too near each other, to give to the rock in which they occur an undisputed claim to the title of stratiform.

The strata of Mont Blanc, according to Saussure[b], though horizontal, are not more than three or four in number, the height of that mountain being between fourteen and fifteen thousand feet.

Fissile and slaty beds necessarily exhibit parallel planes, yet many geologists do not allow them to be stratified.[c]

[a] Mineral Kingdom, 2d ed. vol. i. p. 422.

[b] Voyages aux Alpes.

[c] " Although the slaty structure points out to us the
" direction which the strata must have, it does not follow
" that a rock having a slaty structure is stratified." — Jameson's Min. vol. iii. p. 54. See also Journ. des M. vol. xxvi. p. 173.

The slates in the canton of Glaris, interesting to naturalists on account of the fishes with which they are impressed, have been observed to be alternately thick and thin: M. Wittenbach, at Berne, threw out to me a very ingenious hypothesis to explain this singular fact: he supposed the thick slates formed by the ebb-tide, and the thin by the flood: in his opinion, then these slates could be no other than strata.

4th. Two or more sets of parallel planes sometimes occur in the same rock, so as to meet perpendicularly or obliquely.

At Ilfracombe, nodules of limestone occur in lines which form nearly a right angle with the planes of the slate in which they are contained: in the same neighbourhood may be seen parallel interrupted veins of quartz disposed in echellon, which also cross the planes of the strata. At Hedington Quarries, near Oxford, and at Anthony Hill, near Bath, the laminæ of the freestone are unconformable to the larger divisions. Mr. Townsend[a] mentions an appearance of the

[a] Townsend's Moses, p. 200.

same kind at Burnt-house Gate, and at Swanwick, on the road from Bath to Glocester; at Buckland Point, in the parish of Mells, he found rhomboidal beds of oolite truncated, perfectly smooth in the superior and inferior surface, dipping at an angle of 40°, and confined between two horizontal beds of clay.

At Westow, five miles from New Malton, may be seen horizontal beds of oolite resting on highly inclined ones. To those who wish other examples of this phenomenon, I recommend an examination of the red sandstone of Bridgenorth, or the Pennant stone of the neighbourhood of Bristol.

Dr. Pacard[a], describing lines which cross each other, one set being vertical, the other horizontal, says, that this phenomenon may be seen, among other places, in the gypsum quarries at Mont Martre. [b]La Metherie tells us, that granite is in general split in all directions; that the fissures, when parallel, may at first sight be confounded with seams

[a] Journ. de Physique, vol. xviii. p. 185.

[b] La Metherie, Theorie de la Terre, vol. iv. p. 352.

of stratification; but on looking more attentively we perceive they are not so.

Breislak[a], alluding to a remark of Pallas, says, that though many rocks of granite give one the idea of strata several feet thick, they are only rents which divide the rock into large parallelopipedons, and are to be viewed in the same light as the articulations of basalt.

One thing I must mention, says [b]Gruber, as occasioning me great perplexity, a perplexity which long experience alone would enable me to overcome: the rhomboidal clefts that occur in primitive districts and observe a mutual parallelism. At Aeskerbe the Elbe falls over a natural trellis formed by these clefts. At the Schnee-grube, and other mountains in the neighbourhood, you would suppose what you saw in the distance to be columnar basalt; on a nearer approach, however, it proves to be a large grained granite with parallel and vertical fissures.

[a] Breislak Geol. p. 156.

[b] Gruber's Riesengeb. p. 191. 4to.

At Luce Hill, a remarkable quarry, five miles from Hereford, the trap exhibits parallel fissures and stripes intersecting each other: similar appearances present themselves in the limestone rocks near Tenby, in Pembrokeshire, and in the slate rocks at Plymouth. At a projecting crag of greywacke, near Howth, on the shore of Dublin Bay, the position of the strata would seem to vary with that of the spectator, as in the hall of Greenwich Hospital, the eyes of a portrait on the ceiling appear to follow him to every part of the room. In slate rocks I know not of any criterion by which the planes of cleavage can be distinguished from those of stratification.

5. In rocks that have the appearance of deposition, the planes are not always parallel.

This happens by the very terms of the proposition in regard to all those strata which are said to be mantle-shaped, saddle-shaped [a], shield-shaped.

[a] Combles à deux croupes—demi combles—combles à croupes inegales ou λ. See l'Encycl. Geog. Phys. vol. iii. p. 442.

Mr. Jameson has observed, that we sometimes find seams of several strata terminating in the substance of a larger stratum, and this in the substance of a stratum still larger. The red sandstone of Bridgenorth, Bromsgrove, Newton Ardes, near Belfast, &c. is admirably calculated for the study of this phenomenon.

In mountains of granite, where no other parallelism is observable, it often happens that the crystals of feldspar[a], or mica[b], lie in the same direction.

5. The thickness of masses[c] varies considerably in different parts of their course.

It was the opinion of Buffon[d], that

There is a fine example of shield-shaped stratification on the road from Freyberg to Dresden. The finest I am acquainted with in Britain is at Coolnacarton, near Ballynahinch, in the county of Galway.

[a] Deluc's Travels.

[b] Dolomieu Journ. des M. vol. vii. p. 426.

[c] I employ the word masses to express the *Gebirgsarten* of the Germans, not venturing, as some writers have done, to apply the word Rock, associated from time immemorial, with the idea of hardness and solidity to the contents of a sand or clay pit.

[d] Buffon, v. i. p. 172.

every stratum, whether horizontal or inclined, was of an equal thickness throughout its whole extent; and so it should be in Wernerian[a] language by the terms of the definition. Mr. Playfair[b], adopting this idea, considers it a striking peculiarity of the Toadstone of Derbyshire, that even when there is a thick covering of strata over it, it has been found, by sinking perpendicular shafts, to vary from the thickness of eighteen yards to more than sixty, within the horizontal distance of less than a furlong. He insists on the cuneiform shape which the rock at Salisbury Crag takes at its extremities, and the great difference of thickness at them and in the middle, as an argument extremely favourable to the Huttonian hypothesis: he affirms that nothing of this kind is ever found to take place in those beds of rock which are certainly known to originate from aqueous deposition, and that no character can more strongly mark an essential difference of formation.

[a] Jameson's Mineralogy, vol. iii. p. 51.

[b] Illustrations, p. 294.

Mr. Farey[a], on the other hand, considers the wedge-like form a distinctive character of alluvial matters; these, he tells us, never appear stratified in the uniform manner peculiar to regular strata, but the beds, when sunk through, frequently feather out, or are wedge-like, and intermix with each other.

Where the same property is represented as characteristic of substances so different, the presumption is that it will not be found characteristic of any.

In the Memoir of Cuvier[b] and Brongniart on the environs of Paris, it is stated, that before the later formations, mentioned in that memoir, were deposited, the chalk upon which they rest must have presented a surface varied with depressions and protuberances. These inequalities are clearly ascertained by the islands and promontories of chalk which occasionally penetrate the

[a] Farey's Survey of Derbyshire p. 131. See also his Remarks on the Stratification of France and England, in Philosophical Magazine.

[b] Recherches sur les Ossemens Fossiles, tom. i. p. 14 and 15.

incumbent beds, and by the very uncertain depth at which that substance is found in wells and excavations. It is also stated, that the thickness of the plastic clay varies from sixteen metres and more, to one or two decimetres.

The same irregularity is described by Williams[a] as occurring in strong beds of the mountain limestone. — "In many "places," he says, "I have seen the lime-"rock swell out and increase from two or "three fathoms to more than a hundred "fathoms thick."

In another[b] part of his work, this Author makes a similar observation in regard to coal. "The same individual "seam," he says, "seldom preserves the "same thickness to the extent of four or "five miles on the line of bearing; I have "seen some so variable, that you could "not depend on finding the coal equally "thick for twenty yards together in any "part of the field."

Some striking instances of the wedge-

[a] Min. Kingd. edit. 2. vol. i. p. 403. See also p. 57.
[b] Ibid. p. 60.

like form of the stone-bands, which occur in the coal-mines of Newcastle, are recorded by Mr. Winch in the Transactions of the Geological Society. [a] The same phenomena may be conveniently observed in the beds of sandstone, limestone, and slate, at Bangor Ferry.

"If," says Mr. Aikin [b], "we confine our "attention to those beds which lie between "the big and little *flints*, and which con- "stitute by far the most regular part of the "great coal-field of Shropshire, we shall "find that the *pennystone* bed, which, in "the Madeley pit, varies in thickness from "six to eight feet, is fifteen feet thick at "Lightmoor, about twenty feet at Dawley, "sixteen feet at Old Park, and eighteen "feet at Ketley; that the Viger coal, with "its superincumbent clay, occupies a "thickness of about twelve feet at Made- "ley, is diminished to three feet at Light- "moor, and is entirely wanting in all the "collieries which lie to the north of the

[a] Geological Transactions, vol. iv. p. 12.
[b] Ibid. vol. i. p. 198.

" latter; that a bed of clay, usually known " by the name of the *Upper Clunches*, " bears a thickness of from fifteen to " twenty-six feet in all the above-men- " tioned collieries, except that of Ketley, " where it is entirely wanting."

I am told by a person on whose authority I can rely, that near Ashby de la Zouche, the *bend*, separating the second and third seam of coal, is, in the easternmost coal-pits, thirty-three yards thick; in the next, to the west, twenty-five; in the most western only fourteen; and that in the Bedworth collieries, about half a mile further to the west than these, it vanishes entirely, the second and third coal-seam running together.

Robinson[a], generalizing this observation, ascribes the wedge-like shape to all coal whatever. " As in all classes of coal the " seams gradually increase in thickness " till they come to their full height and " growth, so they gradually decrease till

[a] Essay towards a Nat. Hist. of Westmoreland and Cumberland, p. 49.

" they dwindle out into small seams, and " then the covers change and the coal goes " out."

Dr. Holland[a] informs us, that in Cheshire there seems to be a progressive thinning of the upper bed of salt from north-west to south-east. " In the mines sunk near " the west or north-west of the salt district, " the thickness of this bed has been gene- " rally twenty-eight, twenty-nine, or thirty " yards; proceeding towards the east, or " south-east, it decreases to twenty-five, and " towards the eastern boundary to twenty, " eighteen, and seventeen yards."

Prof. Jameson[b] says, " that the sandstone " and lime-rock, in the river district of the " Forth, afford many examples of this kind."

" However we may be struck," says Von Buch[c], " with the circumstance that the " porphyry under the zircon syenit, at " Gretsen, does not, perhaps, reach a hun- " dred feet in thickness, and rises within

[a] Geological Transactions, vol. i. p. 43.

[b] Von Buch's Norway, p. 67. Note in Mr. Black's Translation.

[c] Ibid. p. 66.

" four English miles from thence to the " height of thirteen hundred feet and up- " wards, such examples are not altogether " new in geognosy; opposite Ringerige, in " the same neighbourhood the sandstone " beneath this porphry is above eight " hundred feet thick; but at Gretsen and " at Giellebeck it entirely fails."

Mr. Jameson observes, " that great in- " equality in the thickness of beds of por- " phyry and sandstone is a common ap- " pearance in Great Britain."

The *liegende Stocke* of the [a] Germans (lying masses, if literally translated, but which I would rather distinguish by the name of lenticular masses), are defined to be portions of earthy or metallic matter, in form somewhat resembling a wool-sack, contemporaneous, but not co-extensive, with the beds in which they lie: their ordinary length and breadth may be from twenty to fifty fathom; their thickness from ten to twenty; they taper off in both directions, from the middle towards the extremities. Rock-salt, and the ores of

[a] Jameson's Mineralogy, vol. iii. p. 226.

iron and copper, are particularly remarked as occurring in masses of this description.

According to Mr. Jameson, these lenticular masses are rarely seen in primitive but more frequently in flötz mountains: otherwise I should have said that granite, sienit, hornblend-rock, and greenstone-rock were more usually found under these circumstances than any other.

6. The term Stratification is by no means unconnected with theory. To constitute a Stratum it is not enough, in the opinion of many geologists, that a substance divides in parallel planes, unless it does so in consequence of the manner in which its particles were at first deposited from a fluid menstruum; now it is obvious that as long as the propriety of using the term depends on the idea we entertain of the manner in which strata were formed, unity of opinion can alone preclude confusion of language. Let us enquire, therefore, how far geologists agree in their opinions upon this subject.

It was the opinion of Woodward, and, I believe, of all other geologists who wrote during the last century, that strata were the effects of deposition alternately suspended and renewed; that the loose materials from which they were formed subsiding at the bottom of the sea, and naturally yielding on the side opposite to that where the pressure was greatest, had arranged themselves in horizontal layers, the vibration of the incumbent fluid, by impressing a slight motion backward and forward on the materials of these layers, naturally assisting the accuracy of their level.

In this mode is supposed to have been formed the first horizontal stratum. New materials, furnished at successive periods, would obey the same law, and the surfaces of each stratum being parallel to that of the water from which it was deposited, would be parallel to that of every other stratum.

That an interval of time, greater or smaller, elapsed between the several depositions, seems ascertained. At Ingleton,

limestone is separated from the rock beneath it by the intervention of loose pebbles, perfectly agreeing in substance with the rock they cover. The oolite at Marquise, near Boulogne, reposes on a bed of marble, the upper surface of which is furrowed by water and perforated by vermiculi.

To these arguments may be added another furnished by the frequency of way-boards, of coral reefs, of beds of shells, and the extraordinary circumstance, now so much insisted upon, of shells peculiar to fresh-water alternately covering and being covered by other shells, which belong only to the sea.

If it is difficult to conceive the existence of so large a quantity of water as would be necessary, under present circumstances, to hold the entire globe in solution; that difficulty, if not removed, is at least much diminished, by supposing the different parts to have been in solution at different periods.

Again, it has been argued, that had the deposition proceeded uninterruptedly, the particles deposited, instead of being ar-

ranged as we now find them, must have followed each other in the order of their specific gravity. An argument particularly applicable to the cases of beds of brecchia and sandstone.

It seems highly probable, therefore, that the parallel planes which the surface of different beds exhibit, are, in many cases, the effects of deposition alternately suspended and renewed; but that they are not so in every case may be inferred, I think, with equal confidence, from the following considerations: —

1. Parallelism of surface alone does not prove that the rock in which it is observable has been deposited by water; for parallelism may be produced by other causes, as every one admits, in basaltic pillars, in backs and cutters, in the laminæ of crystals. In beds of fibrous gypsum, tabular flint, &c., though the external surfaces are parallel, it is evident from an examination of the interior structure, that these beds have been formed, not by the

superposition of successive particles, but by crystalline shoots from the upper and lower surfaces towards the middle. The cheeks of mineral veins, or dykes, are sometimes parallel for a considerable distance, though they cannot be supposed to have derived this parallelism from a disposition to conform to the horizontal surface of a fluid.

2. The more or less frequent recurrence of parallel planes depends on the nature of the substance deposited. Granite, porphyry, serpentine, trap-rock, salt, chalk, are seldom, if ever, found in other than thick masses. Argillite as constantly in flakes: sandstone and oolite in beds of moderate thickness. It is a remark of Bergman[a], that granular rocks are seldom stratified. Williams observed[b], that brecchia appeared stratified, or not, in proportion to the size of the component parts. Townson[c] made the same observation at Grau, in Hungary. Where the brecchia is

[a] Journ. des M. vol. iii. p. 66. [b] Mineral Kingdom.
[c] Travels in Hungary, p. 62.

very coarse, nothing like stratification, he says, is to be perceived; but in the same hill the brecchia is often as fine as a sandstone, and is then more or less distinctly stratified. He adds, that the same thing happens in these kingdoms, and particularly in the neighbourhood of Edinburgh.

3. The larger divisions of rocks are frequently not parallel to the lamina, of which these rocks are composed.

4. In regard to way-boards they seem to depend no less on the nature of the adjoining rocks, than on the circumstances which attended their formation. Stony beds generally have them, but sands, clays, loams, are divided from one another only by a change of colour or very imperfect suture; and in those substances which are called primitive, no way-boards have yet been discovered.

Catcott has given a philosophical explanation of this phenomenon. "If you take "a certain portion of earthy bodies, and

" pulverize them to the finest degree ima-
" ginable, and mix them as confusedly
" together as possible, and let them fall
" through a dry fluid, such as the air, they
" will settle just in the same confused state
" as they were; if you permit them to sub-
" side through water, they will settle more
" or less in parallel strata. Indeed it re-
" quires twenty or thirty times the quantity
" of water to earth to make this layer-like
" subsidence tolerably apparent even in
" the mixture of but three or four bodies;
" but the greater quantity of water you
" use, and the finer you pulverize the sub-
" stances, the more apparent and regular
" the strata will be." (P. 269.)

According to Werner, strata are from four to six feet apart in the older formations, but less distant in the newer.

Hutchinson observes [a], " that in the mid-
" land counties of England the strata are
" commonly thin near the surface, and be-
" come gradually thicker in proportion to

[a] Hutchinson's Works, vol. xii. p. 264.

" their depth ; but no thin strata whatever
" are found in Cornwall."

" At La Porte de France, one of the
" quarries at Grenoble, the lower beds are
" thin and laminated, rather slate than
" limestone; higher up they are thicker
" and more calcareous. In the middle are
" procured large blocks of marble. Above
" these beds are others of common lime-
" stone, and the remaining ones, as they are
" successively softer, less calcareous, more
" argillaceous, as they approach nearer the
" surface, successively diminish in thick-
" ness."

Townsend remarks, that no soil such as covers the present surface of the earth is found between the strata.

5. At the junction of two kinds of rock, as greywacke slate, and limestone, sandstone, and trap, chalk and green sand, we often find that each is impregnated with the substance of the other.

6. The contemperaneous veins of one

stratum sometimes extend themselves into the adjoining stratum.

At Mouzainville, a village between Varennes and Verdun, M. Ferrusac[a] observed a bed of grey limestone, six feet thick, lying horizontally between beds of clay: in some places the two external beds were traversed by veins issuing from the third: in others they graduated into each other, and amalgamated: at an adjacent quarry they again appeared distinct, but the intermediate one was greatly changed in quality and thickness: presently this intermediate one blended with its neighbours, sent out a fork, ramified, was lost: yet the total thickness of the three beds continued uniformly the same.

Cuvier, carried away by natural partiality to the subjects which have most engaged his attention, is, perhaps, a little unjust towards those which have escaped it. According to him, neither way-boards, nor pebbles of known rocks imbedded in other rocks, nor horizontal strata resting upon inclined ones, could ever have led to the

[a] Journal de Physique, vol. xv. p. 453.

supposition that one part of our globe was older than another. "Is it not clear," he exclaims, "that we are indebted for "a theory of the earth to fossils only? "Without them, who would have dreamt "of the globe having been formed at "successive epochs, and by a series of dif- "ferent operations? It is only by analogy "that we extend to primitive districts the "conclusions which fossils enable us to "form in regard to secondary districts; "if all strata had been without fossils, no "one could maintain that they were not "all formed at the same period." [a]

7. Decomposition, or torrefaction, will often expose to view stratification previously latent; the slate of the Cotswolds has no appearance of slate till acted upon by the frost; and for a similar reason the upper beds of every quarry are in general thinner than those beneath them.

8. "Depositions which go on uninter-

[a] Cuvier's Recherches sur les Ossemens Fossiles, tom. i. p. 35.

" ruptedly in our laboratories arrange them-
" selves in distinct layers."

Such are the arguments which induce me to think with M. Ferrusac[a], and Mr. Jameson[b], that contiguous strata may in some instances be contemporaneous.

The various postures which rocks assume give rise also to much diversity of opinion.

The position of masses is determined by the direction and inclination, or the dip[c] and inclination, observed through their whole extent.

Their Direction is the position with regard to the meridian of an imaginary

[a] Journal de Physique, vol. xv. p. 454.
[b] Wernerian Transactions, vol. ii. p. 225.
[c] For the Wernerian definition of these terms, see Journal des Mines, vol. xxvi. p. 170.

straight line, formed by the intersection of their planes with that of the horizon.

Their Dip is the position with regard to the meridian of an imaginary horizontal line drawn at right angles to the line of direction.

Their Inclination is the measure of the angle formed by the intersection of their planes with that of the horizon.

If the direction is given, the dip is determined, and if the dip is given, the direction is determined.[a]

The instruments required for determining the position of a mass, are a compass and clinometer.

The Clinometer presented to the Geological Society by Lord Webb Seymour, would be perfect, if sufficiently portable. A smaller one, constructed by Mr. Jaffray, has the advantage of enabling us to determine the dip by measuring any two sections of a stratum, provided they are

[a] Pini was one of the first writers who felt the importance of recording the dip and direction of beds, (see his Observations on St. Gothard); practical miners, however, must have attended to this subject much earlier.

not parallel to each other. With the common clinometer, when the planes of a stratum are inaccessible, the sections measured must be adjacent.

All that a clinometer will teach us, however, is the posture of a mass in the precise spot where it is examined; but the direction and dip may be very different in one part of a country from what they are in another: thus in Kent, the chalk dips to the North, in Sussex to the South, in Wiltshire to the East, in part of Hampshire to the West. This instrument is, therefore, by no means adapted to the use of those whose object it is to discover the average of dip.

In using the compass, we should bear in mind that many rocks are magnetic; and in recording our observations with this instrument, should state whether we have allowed for its variation.

In Germany, the miners' compass is graduated as a dial, divided into twenty-four parts, or hours: by those who employ

it, a stratum dipping to the East is said to dip to six o'clock.

In the scientific language of this country, it is usual to express the inclination of a bed by the angle it makes with the horizon; but the expression among labouring people is, it dips so many inches in the yard.

In travelling over an extent of country, the direction of the beds is characterized by sameness and uniformity. Every slope is opposed to another of corresponding steepness, unless when other causes operate so as to render insensible the operation of this. There is little variety in the productions of the land, or the condition and employment of the inhabitants. In travelling along the line of dip, on the contrary, our eyes are continually regaled with a change of scenery. Every hill has a character of its own, and is succeeded either by hills of a different character, or not unfrequently by a flat. Where the ascent is steep on one side, the descent is gradual on the other. Commons succeed to inclosures, pasture to arable, wolds to marshes, a

naked district to a forest, a poor soil to one remarkable for its fertility, and *vice versa*. The valleys extend principally to the right and left, rarely showing themselves in front. The employment of the people is various, and the fences and buildings are constructed of different materials.

In crossing strata obliquely, these characters are combined.

THE POSITIONS OF MASSES.

The positions of masses and strata have been classed by the writers of the Encyclopedie[a] under the following heads: 1. parallel to the horizon; 2. perpendicular; 3. inclined[b]; 4. curved inwards; 5. curved outwards; 6. curved upwards; 7. curved

[a] Encyclopedie Geog. Physique, vol. i. p. 32.

[b] Mr. Pinkerton recommends that we should forego the use of the term strata, as applied to inclined masses, substituting the term Arrects; but if this recommendation were adopted, I fear we should lose more in sound than we should gain in sense.

downwards; 8. circular; 9. undulating; 10. zigzag.

It has been supposed, that the primitive rocks were always vertically, the secondary horizontally, stratified. It is true, that vertical planes occur more frequently in the older rocks than in the newer; but it is also true, that every rock, in different parts of its course, exhibits both these appearances.

At St. Roch, on the south side of the Alps, and near Cresciano, Granite, according to Saussure [a], is horizontally stratified. Deluc, in his letters to Professor Blumenbach, mentions another instance at Missouri. Dr. Mitchell [b] and Mr. Jameson observed the same thing at the Riesengebirge. Charpentier [c] tells us, of Granite in Saxony which is horizontal. Bergman [d] also speaks of horizontal Granite, though

[a] Voyages, § 1752.

[b] Nicholson's Journal, vol. ii. p. 227.

[c] Charpentier's Mineralogische Geographie der Churſachsischen Lande, p. 17 and 389.

[d] Journal des Mines, vol. iii. p. 75.

without specifying the exact place at which he had observed granite in this position.

Saussure [a] found Gneiss horizontal at Monte Rosa. I have seen it lying horizontally upon a bed of feldspar-porphyry, near Nieder Schonau, on the road from Freyberg to Drësden, and Charpentier tells us that this is its usual position.

In the neighbourhood of Freyberg, it is commonly thought that the Gneiss is more horizontal than the mica-slate, and the mica-slate than the clay-slate. Between Mohorn and Herzogswald, the clay-slate appeared to me to form an angle with the horizon of between 20° and 30°, the mica-slate between 15° and 20°.

Horizontal beds of Hornstone-slate have been observed by Bergman [b] at several places on the confines of Jemteland and Norway.

M. Picot de la Peyrouse [c] says, "that ho-

[a] Voyages, § 2138.

[b] Bergman Physicalische Beschreibung der Erdkugel, 3d edition, vol. i. p. 192. vol. iii. p. 75.

[c] Journal des Mines, vol. vii. p. 51.

"rizontal strata of primitive Limestone al-
" ternate in one part of the Pyrenees, with
" horizontal strata of Corneenne. The beds
" of Limestone which occur in Sienite, be-
" tween Meissen and Dresden, are also hori-
" zontal."

The Slate of Wales and Cumberland is in some places horizontal.[a]

On the other hand, there is perhaps no rock which does not occasionally appear in strata, inclined at a considerable angle to the horizon.

It has been observed, that the secondary Sandstones and Limestones[a] of the Pyrenees, are often vertical, and that a dip of less than 45° is a circumstance almost as rare at the base of these mountains as at the summit, at the extremities as in the centre of the chain.

The high inclination of the Sandstone of the Vallorsine, so much insisted upon by Saussure, is analogous to what we find at

[a] Journal des Mines, vol. xii. p. 88.

the Lecky in Worcestershire, at Alderley-edge in Cheshire, in the district of Gower, and the Ridgeway in Pembrokeshire. At Callendar, in Scotland, the old Conglomerate lies in beds absolutely vertical.

The Transition [a], or Mountain Limestone, is nearly vertical at Caldey Island, at Tenby, Dunraven, the Mumbles, the Clee hills, &c. &c.

The Magnesian Limestone at Bredon, in Leicestershire, forms with the horizon an angle of at least 45°.

The Coal measures of this Country are often inclined at a very considerable angle; those at Talbenny, in Pembrokeshire, are nearly vertical.

At Brancilli [b], near La Claitte, in Flanders, their dip varies from 60° to 70°, and at the hills of St. Giles [c], near Liege, they

[a] The mountain Limestone is the transition Limestone of Werner, not, as is usually supposed, the first flötz.

[b] La Metherie, Theorie de la Terre, vol. v. p. 59. and vol. iv. p. 153.

[c] l'Encycl. Geographie Physique, vol. i. p. 709.

assume every position from the vertical to the horizontal.

The Red Marl has a very considerable dip[a] on the east side of Catton in Croxall.

Near Little Stoke, in Somersetshire, the Lias[b] is vertical. I have seen it vertical also at Eckersberg, north-east of Jena, where the disturbance has been so great, that in one place the red marl would seem to rest upon it.

Vertical or highly inclined beds of Chalk occur at Handfast Point on the coast of Dorsetshire, at the Hog's back in Surrey, the Needles in the Isle of Wight, &c.

At Alum Bay, the Clays and Sands that cover the chalk are vertical.

It has been erroneously imagined by some writers, that all rocks are horizontal in plains, and inclined in mountains.

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[a] Tilloch's Magazine, March 1810, p. 186.

[b] Geological Transactions, vol. iii. p. 373.

Was the inclination of masses and strata given to them at the time of their deposition, or has it been the result of subsequent catastrophes?

The following arguments have been adduced to prove the strata originally horizontal.

1. It is not unusual to observe upon the opposite sides of a fault the same strata following each other in the same order, but having their planes on the one side parallel to the horizon, on the other inclined: there can be little doubt that these were originally continuous, and that one of them has shifted its position. Now, it is infinitely more reasonable to suppose, that the disturbance which occasioned this change, has thrown the strata out of their horizontal bearing than into it. This argument is therefore conclusive in all cases to which it applies.

2. In some cases an original inclination of the strata seems incompatible with the

nature of their materials. Can it be believed, that the unconsolidated sand and marl of Alum bay, now vertical, has been vertical from the beginning? In the neighbourhood of Bristol, two series of beds, similar in character, but differing materially in respect of age, occur in very different positions; the strata of old red are nearly vertical, those of the newer red nearly horizontal; is it not highly probable that they were in the first instance both horizontal? "It is impossible," says Mr. Aikin[a], speaking of a rock in Shropshire, "that a bed "of sandstone, and much more of clay, "marl, or mud, as it no doubt was in its "original state, should have been disposed on a plane, at an elevation of from "30° to 40°, in such a manner as to constitute an extensive stratum of a uniform "thickness, and that hardly exceeding a "foot for a depth of at least a hundred "feet."

"The Tubulites, which pierce the "marl at Steeraway, lead to the same "conclusion: some of these, twelve inches

[a] Geological Transactions, vol. i. p. 206.

" in length, and scarcely the eighth of an inch
" in diameter, being perpendicular to the
" planes of the stratum, are inclined at an
" angle of 50° to the horizon, now it is the
" known habit of these animals to affect
" a vertical position, with regard to the
" horizon."

The manner in which the pebbles and bowlder-stones occur in the older brecchias, renders it impossible that beds of this description should have possessed originally their present inclination. Where pebbles[a] lie in veins, as in the Relistian mine, they are disposed horizontally in the order of their specific gravities; whereas, in these conglomerates, they are disposed in that which would have been the order of their respective gravities, if the beds had been horizontal; consequently they could not remain an instant in their present position if the cement which unites them were to become soft.

This argument first suggested itself to M. Saussure on examining the celebrated pud-

[a] Philosophical Transactions, see also Werner on Veins, p. 61.

ding stone of the Valorsine: the importance which Dolomieu attached to it will be seen by the following passage.

"This consequence[a] (viz. that rocks "were originally horizontal) has been con- "firmed by the beautiful observations of "M. de Saussure. He it was who, by find- "ing beds of rolled stones, first established "the fact, the most important there is in "Geology, that the beds on which these "stones lie were once horizontal, and both "subsequently thrown out of their position "together. The shifting of these beds, "then, may be placed among those funda- "mental truths which serve as a founda- "tion for all systems. I have long felt "the necessity of admitting it, but for M. "de Saussure was reserved the honour "of proving it. He has done more for the "advancement of Geology than all the na- "turalists who preceded him."

M. Deluc acquiesces in the panegyric just quoted; after recording M. de Saussure's change of opinion, (for at first he supposed

[a] Journal de Physique, vol. xxxix. p. 384.

inclined strata to have been always inclined,) and his motive in altering it;— "thus," he says, "has he diffused upon Geology a "light which can never be ob- "scured; whoever shall attentively study "the nature of mountains, as I have "done since I have had that light to "guide me, in a variety of countries, will "every where find the same phenomena, "which through the eye irresistibly speak "to the understanding."

Werner [a] noticed a conglomerate in the coal-field of Hainichen, composed almost entirely of flat pieces of clay-slate of considerable size, having in some places a position nearly vertical, the same with that of the strata: it is impossible, he observes, that these stones should have been arranged in this manner by the action of water; they must therefore have taken their position afterwards along with the strata. The pebbles contained in the inclined

[a] Werner's Theory of the Formation of Veins, translated by C. Anderson, M.D. p. 60.

"strata" of sandstone at Nottingham have the flat side downwards.

3. Sir James Hall [a], describing the inclined and contorted strata near St. Abb's head in Berwickshire, remarks, that many of the beds possess that peculiar undulation on their surface which we meet with on a sandy beach when the tide has left it, and which affords the most unequivocal indication of aqueous deposition. If so, the inclination of these beds cannot be of the same date as themselves.

4. Now, if it be admitted, that in the instances above-mentioned, the present position of the beds is not their original position, it seems extremely difficult not to admit more; for the inclination of these is often the same as the inclination of the beds immediately beneath,

[a] Edinburgh Transactions, vol. vii. p. 82. In this memoir, the author supposes the killas (as he calls it, I think improperly) to have shifted its position since the red sandstone was deposited.

so that it appears very improbable that any one should have shifted its place, while the others retained it: of this, Saussure has given instances in Switzerland, and our own country affords many; in Wales, and more strikingly perhaps in the south of Ireland, the conglomerate rock is so intimately connected with the sandstone and slate of transition (if I may use that term), and these again with the older rocks, that it is hard to say where the series begins or terminates. No catastrophe can be supposed to have affected one without affecting the whole.

The interposition of pudding-stone, says Deluc [a], begins even among the primordial strata. Saussure has seen it between granites and shisti, between shisti and calcareous strata, between calcareous strata and sandstone.

These are the principal arguments that occur to me on the one side: let us enumerate those which may be brought forward on the other.

[a] Deluc on Geology, p. 374.

1. It is evident from the nature of veins, that under favorable circumstances the particles of matter may arrange themselves in beds highly inclined to the horizon. We obtain the same conclusion from a circumstance already noticed, that the laminæ of rocks are often inclined where the strata themselves are horizontal. Within a mile of Cernioge, the stripes are at right angles to the laminæ of the slate on which they occur: here then is another instance of correct parallelism, without the aid of horizontal deposition.

2. Inclined strata are frequently unaccompanied by any mark of violence, and exhibit the greatest regularity both in form and direction.

Whatever difficulties may be involved in the contrary hypothesis, M. Cordier[a] is startled at the introduction of a force which could displace the entire chain of the Pyrenees at once, and yet be so regular in its direction as to leave traces of its effect in a straight line only.

[a] Cordier, Journal des Mines, vol. xvi. p. 280.

Picot de la Peyrouse[a], describing the same mountains tells us, that the regularity, the sportiveness, the caprice of the vertical beds of sand and limestone, heterogeneous nodules of one rock in the heart of another, the uniform verticality of the beds which compose the primitive ridges and secondary summits, vertical beds traversed by horizontal ones, preclude the idea of any sudden or irregular force having shifted the rocks of the Pyrenees into their actual posture from one originally horizontal.

Humboldt[b] has observed "strata" of clay-slate dipping N.W. at an angle of 70° for fifteen successive leagues. Can it be imagined that these strata were once horizontal, and consequently fifteen leagues thick? or that falling, they found a chasm large enough to receive them? But he goes further, and maintains this to be the common inclination of all primitive strata throughout the globe. His argument would be strong, if the facts

[a] Journal des Mines, vol. vii. p. 65.
[b] Journal de Physique, vol. liii. p. 47.

on which he grounds it were well established.

3. Beds[a] which are vertical, or inclined at a considerable angle to the horizon, are, in many cases, broader at the base than they are at the summit, or, in other words, mantle-shaped. This form can hardly have been given to them by any change of posture subsequent to their consolidation.

4. M. von Buch[b] derives an argument in favour of the original inclination of rocks from the change which is often observed in their nature on the opposite sides of a granitic chain: thus, on the Italian side of the Alps, and between Bolzano and Brixen, in the Tyrol, porphyry is very abundant, constituting eminences four thousand feet above the level of the sea; but this rock fails altogether on the side of Germany and Switzerland. On the northern side, mag-

[a] "Beds which are perpendicular at the surface of "the earth become gradually more horizontal as they "descend." Jameson's Mineralogy, 1st edit. vol. iii. p. 224.

[b] Journal de Physique, vol. xlix. p. 212.

nesian rocks abound, which are extremely rare on the southern. If these rocks derived their inclined posture from elevation or subsidence, why are they not found on both sides of the chain?

Secondary Limestone occurs very abundantly on the north-eastern flank of the primitive chains in Saxony, and Bohemia, the Alps, the Carpacks, and even in North America; but very sparingly on the south-eastern flank of those chains.

The coal-measures on the opposite sides of the Derbyshire limestone are dissimilar, and the shisti on the opposite sides of the Ocrinian chain.

Humboldt[a] remarks, that the direction of high chains of mountains seems to have great influence on the direction of strata, even at a considerable distance. Of this influence which Humboldt has observed in the Pyrenees and in Mexico Ebel[b] has discovered numerous instances in the Alps.

5. The irregularities observed in the stratification of some beds seem to warrant the

[a] Journal de Physique, vol. lxxi. p. 372.

[b] Ebel, vol. i. p. 220. vol. ii. p. 201. 215. and 357.

opinion that these beds were originally inclined: thus at Malvern [a] the inclination of the sandstone diminishes as it recedes from the hill, and then increases; to this succeed strata of limestone, the inclination of which becomes more and more considerable; these are followed by strata of an argillaceous rock which continue to rise till they become vertical, and then dip westward with a gradually-diminishing angle of inclination.

6. Secondary rocks are generally inclined at their junction with the primary.

7. Secondary rocks are often unconformable to the primitive rocks, on which they rest; in Red Bay, Anglesea, the former dip to S.E., the latter to N.W.

At the head of the lac de Joux, in the Pays de Vaux, vertical beds are said to rest on horizontal ones; perhaps fissure has been confounded with stratification here, as at the Saleve, where the same incon-

[a] Geological Transactions, vol. i. p. 306. See also La Metherie, Theorie de la Terre, vol. v. p. 81. where he describes the Coal-measures near Liege.

gruity has been supposed to prevail between the strata at the base of the hill, and those higher up.[a]

If the beds were originally horizontal, and afterwards shifted, the supposable causes of this shift are, 1. An internal force acting from below upwards, so as to raise the crust of the globe. 2. A want of support, owing to internal cavities, so that the beds have fallen by their own gravity. 3. An external shock which has broken the shell, and made one part tumble over another. Dolomieu[b] was inclined to the last of these opinions.

But to what circumstances can we ascribe this inclination of rocks, if we suppose it original?

[a] The Huttonian doctrine upon this subject is curious. Assuming that all rocks have been forced up once from the bottom of the sea, and primitive rocks twice, it supposes that the primitive rocks have acquired their vertical or inclined posture in consequence of this violent elevation, the secondary in spight of it. — *Playfair's Illustrations*, p. 123.

[b] Journal de Physique, vol. xxxix. p. 385.

1. Mr. Hutchinson[a], who supposes slate and killas to have been deposited mechanically, attributes the inclination of their beds to the shape of their component particles. Bodies of such a flaky form, he conceives, would subside edgeways. In coal-measures, however, we know that slate is found in a posture nearly horizontal.

2. Many authors[b] ascribe the original inclination of strata to an inequality in the base or ground on which they were deposited. The figure of the lower beds deposited on an uneven surface would necessarily be affected, says Mr. Playfair[c], by two causes, the inclination of that surface, on the one hand, and the tendency to horizontality on the other; but as the former cause would grow less powerful as the distance from the bottom increased, the latter cause would finally prevail, so that the upper beds would approach to horizontality, and the lower would neither be

[a] Hutchinson's Works, vol. xii.

[b] La Metherie, Theorie de la Terre, vol. v. p. 55. Jameson's Mineralogy, 1st edit. vol. iii. p. 55.

[c] Illustrations, p. 43.

exactly parallel to them, nor to one another. In a small work published by the famous enthusiast Swedenberg [a] in 1722, the following experiment is recorded:

"Mud and water, well mixed together, "being poured into a vessel, the bottom "of which was conical, subsided hori- "zontally: the form of the bottom did "not produce any effect. More mud and "water being thrown in, the strata de- "posited were still horizontal; but the "mixture being allowed to stand a day "or two, the strata during this time "shrunk considerably towards the edge "of the vessel, and very little towards the "centre; the degree of consolidation "varied as the depth, and the strata "gradually became inclined."

Where this cause has operated, therefore, we ought to find the strata in different parts of their course unequal in thickness and solidity: Does not this happen in mantle-shaped strata?

Dr. Pacard [b] made a series of experiments, with the same view. He found that

[a] Miscellanea, pars i. p. 23.

[b] Journal de Physique, vol. xviii. p. 189.

a quantity of earth or salt suspended in a liquid adhered to the sides of the vessel when inclined, but when upright, was parallel to the surface of the water; and inferred that the obliquity of strata depended wholly on the circumstances under which the deposition took place. May not corpuscular attraction, that agent by which our tea-kettles are coated and our decanters furred, have operated on a more enlarged scale in the formation of veins and strata?

3. Professor Werner[a] was the first, as far as I know, who considered the primitive rocks as composed purely of crystalline matter, without denying them, however, the attributes of stratification: the transition, or those which he supposes to have been produced by the joint agency of crystallization and gravity, are in his system also admitted to be stratified.

In what manner all the parts can be dis-

[a] See an attack on this Theory in the Edinburgh Review, vol. ii. p. 343. and Kirwan's Answer. See also l'Encyl. Geog. Physique, vol. iii. p. 504.

posed according to the laws of crystalline aggregation, while the whole is obedient to those of gravity, is a question natural to ask, and not easy to resolve.

The effects attributed to crystallization by later writers are considerably more extensive. La Metherie could not fail to refer to crystalline agency the divisions of strata and the construction of mountains, since the human form itself appeared to him to be the necessary result of that process. Mr. Jameson is of opinion that strata are analogous to the laminæ of crystals, and viewed on the large scale, would probably be found to meet each other at determinate angles.

All masses and strata are subject to curvature and angularity.

The curvatures of Gneiss are particularly specified by Mr. Jameson * as characteriz-

* Jameson's Mineralogy, 1st edit. vol. iii. and Trans. of Wern. Nat. Hist. Soc. vol. i. p. 290.

ing one of the members of that formation; those of Mica-slate are very conspicuous at Ben Lawers, Ben Lomond, and Glencroe; and what would be remarkable if it were true, it is said that garnets are never found in this description of rock, unless where it is waved. The promontory of Holyhead exhibits to great advantage the inflexions of a Chlorite-slate, in which quartz is predominant; inflexions of Killas and Transition-slate are seen on the coast of Cornwall[a], and Devon; at Aberystwith; in the neighbourhood of Llangollen; at Conway; at Llawrwyst bridge; and on the road from thence to Corwen — of Primitive Marble at Derrowra in Conemara.

The mountain chains of the Continent abound in similar examples.

M. Duhamel[b], speaking of the Pyrenees, says, "compact feldspar (roche de corne), "trap, limestone, form an immense mass, "composed of a prodigious number of al- "ternate beds of no great thickness, and in-

[a] See Geological Transactions, vol. ii. and the Portfolios of Geol. Soc.

[b] Journal des Mines, vol. viii. p. 753. and again p. 750.

" clined to the horizon at a high angle. ' Some of them are plain and regular, while " others twisted in a thousand different " directions, without disturbing the paral- " lelism of the beds above or beneath, give " you the idea of an explosion." Contortions in the Old Red Sandstone are not common in this country; but they are seen at Jedburgh; fine examples occur in the Pyrenees[a] at Port Vieil and la fourche d'Allans. — Near Eckersberg, in Saxony, the Red Ground containing fibrous gypsum is slightly contorted.

At Lucan, and on the shore towards Portrain, north of Dublin, the curvatures of Calp are exceedingly complicated. At Mercaston in Derbyshire, at Chepstow, at Orme's Head, we observe them in Mountain Limestone; — at Bredon hill in Magnesian Limestone; — at Ashford[b] in Limestone Shale; — at Sandsfoot[c] near Tenby, on the

[a] Journal des Mines, vol. vii. p. 54.

[b] Several other instances are given in the Survey of Derbyshire, vol. i. p. 231.

[c] See drawing in possession of the Geol. Soc.

banks of the Dee between Holywell and Mostyn; within a mile of Berwick upon Tweed; and still more strikingly at Liddel Brig near Castleton in Roxburgshire in Coal measures; — at Dunraven and Barry Island in Lias.

The more modern rocks which occur at Purbeck and along the coast of Dorsetshire are often contorted. A very remarkable contorsion of Chalk at Handfast Point, is figured in the work of Sir Henry Englefield. Dr. Pacard * describes a similar inflexion at Mont Martre.

At Port Dinnleyn in Carnarvonshire, I found the same waving lines in sandstone now forming, in the Dunes on the sea shore; and a very fine sand alternating with Coaly Matter, (both of them being alluvial,) forms fan-like or wedge-shaped strata, on the west side of the road which leads from Edinburgh to Leith.

* Journal de Physique, vol. xviii. p. 185.

Examples of striking contorsions in secondary rocks, on the Continent, may be seen in Journal des Mines, vol. xviii. p. 307, and vol. ix. p. 449.

I cannot therefore admit with Mr. Allan[a], that contorsions are characteristic of transition slate; nor subscribe to the more common opinion, that they are peculiar to primary strata, or if found in more recent rocks, found only on the verge of the primary.

The circle, of which these curves are the segments, are sometimes many miles, sometimes only a few inches in diameter.

Mr. Playfair[b] mentions with astonishment, the smallness of some of the curves; other authors have been equally struck with their vastness. In some places, says Williams[c], they are on so large a scale, that the waves of water do not convey an adequate idea of the spacious dimensions of the troughs, and of the extent and magnitude of the ridges. Hutchinson[d] has made use of the same figure. I have never seen the surface of the sea more variously curled in

[a] Allan on Transition Rocks, Edin. Transactions, vol. vii. p. 90. [b] Illustrations, p. 221.
[c] Mineral Kingdom, 2d. edit. vol. i. p. 90.
[d] Hutchinson's Works, vol. xii.

a great storm, than I have seen the grain of the same stratum of killas.

Saussure[a] has compared strata which he observed in various parts of the Alps, to the letters Z S C to a disjointed X, to the Greek Lambda λ, &c.

It is supposed by Mr. Playfair[b], that the curvature is generally, if not universally, simple, like the superficies of a cylinder, not double like that of a sphere;—this is a mistake.

As an instance of curvature extending in both directions, we may mention mantle-shaped strata. This appearance, though it has been most observed in primitive rocks, is by no means peculiar to these; in the north of England the limestone mantles round the slate; the coal-measures of Derbyshire mantle round the limestone.

When masses or strata decline upon every side towards a certain point, they are said to be basin-shaped. Such is the disposition

[a] Saussure, Voyages aux Alpes, § 36. 467. 475.

[b] Illustrations, p. 226.

of the mountain limestone at Ormeshead, of the coal in South Wales, of the chalk in the north of Ireland.

The clam-shell cave at Staffa was probably so named, from the conchoidal form which it derives from curvature in the strata.

It is supposed that on the great Clee hill in Shropshire, there are no less than seven distinct coal-fields; the principal of them is covered by basalt, which varies in thickness from 60 yards to 0, though this coal-field is only two miles in length, and one and a half in breadth: the strata dipping to a common centre, the thickness diminishes towards the circumference.

Another coal-field, a quarter of a mile in diameter, situate on the same hill, crops out in both directions.

In all these cases, the curvature is plainly not cylindrical but spherical.

Let us now consider the probable causes of curvature.

1. According to Dr. Hutton, the strata

having been formed horizontally, were lifted, while flexible and ductile, in a direction from below, upwards; owing to gravity, and the resistance of the mass, this direction became oblique, and the lateral force occasioned contorsions.

Such is Mr. Playfair's[a] statement, and he adds, that the Huttonian theory is no where stronger, than in what relates to the elevation and inflexion of the strata; points in which all others are so egregiously defective.[b] It is with surprize, therefore, that I find one of the most zealous supporters of that theory, allowing us an alternative on this occasion: Sir James Hall[c], supposes that the strata, originally horizontal, have been urged, when in a soft but tough and ductile state, by a powerful force, acting horizontally, and opposed by an insurmountable resistance on the opposite sides; or, that the same effect has been produced by two forces acting in opposite directions, at the same time that the whole was held down by a superincumbent weight,

[a] Illustrations, p. 45. [b] Ibid. p. 234.
[c] Trans. of R. S. E. vol. vii. part i. p. 84.

which, however, was capable of being heaved up by a sufficiently powerful exertion.

In regard to Mr. Playfair's supposition:

1. I do not understand how crystalline strata could be so lifted; while flexible and ductile, because in regard to these there is no middle stage between fluidity and consolidation.

2. From the operation of such a cause would result other indications of disturbance which have not resulted.

3. In many cases no such cause can have operated, for the curved strata rest on horizontal strata in which there is no curvature. The nagelfluh of the Rigi is stratified with the utmost regularity; the limestone which covers it is extremely disturbed and contorted: how happened it that a force which so affected the limestone, elevated from 5 to 7000 feet above the level of the sea, did not affect the nagelfluh beneath?

The limestones of Dudley, Aberly, Longhope, Malvern, &c. the shale of Ashford, the calp of Dublin, are all remarkably contorted, but none of these rest upon contorted strata.

On the coast between Scarborough and Filey, curved strata lie on strata that are not curved; there is a similar instance at Tenby, in South Wales.

4. If we admit the strata to have been elevated, it is easy to imagine that two opposite forces acting upon a body, the stronger upwards, the weaker downwards, should communicate to that body a lateral motion; but will such motion account for the phenomena in question? would it not rather close the fissures which in many cases are not closed? consolidate the mass, which in many cases is not consolidated? if it incurvated the strata, would the curves be cylindrical, or in one direction only? or would they not rather spread like a bush, upwards, North, South, East, and West, forming a species of curve unknown in the history of stratification?

5. If the theory of Mr. Playfair were true, curvature should never be found in those strata that are horizontal, whereas horizontal strata are often curved.

6. The conformity of different strata is another circumstance fatal to this hypothesis. There is no species of rock in which the curves are more frequent or more fantastical than greywacke slate; this rock, we know, in many instances, alternates with conglomerate, the pebbles of which are disposed in such a manner, that it would be impossible for them to remain an instant in the place which they occupy, if the cement which connects them together were to become soft. The conglomerate, therefore, and consequently the slate which alternates with it, could not have been elevated, till after its consolidation. If, then, as the Huttonians say, it was not consolidated till after it was curved; neither was it elevated till after it was curved: in other words, the effect preceded the cause.

In regard to the supposition of Sir James

Hall, it seems to me that the particles being exposed to horizontal pressure (how produced we are not informed, and will not stop to enquire) would ease away to the part where resistance was least. If it were least towards the top, the mass would bulge upwards; but will this explain the complicated phenomena of curvature?

M. de Saussure, speaking of strata, which he found on the road to St. Martin, disposed in the form of a divided X, observes, "These curves are so exactly "true throughout, and so continuous, "that I can never believe the strata "have been horizontal in the first in-"stance, and afterwards thrown into the "fanciful position in which we now be-"hold them. Not only must the mass "have been soft when acted upon by the "disturbing cause, (for there is no appear-"ance of fracture in the most sharp and "sudden inflections,) but it must have been "treated with a gentleness and delicacy "which it is impossible to describe." It is "not in the nature of violent convulsion

" to preserve so carefully the continuity of " the parts." [a]

At the hill on which Dudley Castle is built, the interior strata are very nearly vertical: the exterior are folded round them, and their edges join, after making the circuit of the hill, so as to form a ring. Wren's Nest, another eminence in the neighbourhood of Dudley, is constructed of the same substances, arranged in the same manner.

II. In the Wernerian [b] theory the contorsions of some of the primitive masses are explained upon the principle of crystallization.

This idea, first suggested by Saussure [c], is condemned by Mr. Playfair [d], as unsatisfactory and illusive. The purpose for which crystallization is here introduced, he says, is not to give a specific figure to a particular substance, but to derange the substances, which it has formed and figured according to certain rules, a work which

[a] Voyages aux Alpes, vol. ii. § 475.
[b] Jameson's Mineralogy 1st edit. vol. iii. p. 352.
[c] Voyages aux Alpes, § 159. 475.
[d] Illustrations p. 232.

we know not how it is to perform, and in which we have no experience of its power. Mr. Murray[a] attempts to get over this objection by an appeal to facts; and pointing out the analogy which subsists between the contorsions of entire strata, and the wavings which, on the small scale are seen in alabaster and stalactite, (wavings which Count Bournon[b] ascribes to a change in the direction of the constituent crystals,) infers that as crystallization has produced these appearances in the one case, it may be presumed to have done so in the other. I apprehend it has not produced them in either, and that in reasoning on this subject Mr. Murray has not guarded himself sufficiently against an error to which we are always liable, that of confounding co-existent phenomena with cause and effect. That alternate beds of different substances, such as limestone, sandstone, and slate, should be all curved, as we find them on the coast of Devonshire, and in many

[a] Comparative View of the Huttonian and Neptunian Systems of Geology, p. 109.

[b] Bournon's Traité de la Chaux Carbonatcé, vol. i. p. 187.

other places, seems fatal to the theory which would ascribe these curves to crystallization.

The curvature of masses may perhaps depend, sometimes on an unequal effect, produced by temperature on the materials which compose them; sometimes on the motion of the fluid from which they were deposited; sometimes on the form of the bottom on which they rest.

III. On unequal effect produced by temperature on the materials;

The curvatures which I refer to this head, are analogous to the warping of wood, the curling of parchment, the blistering of paint. It is well known, that trees are flattened in beds of clay or marl. At Newcastle-on-Tyne, a portion of coal being removed, the remainder is allowed to stand for the purpose of supporting the roof; in a few years, however, this support is no longer necessary. The shale bulges out in the interstices, and a new set of pillars now do the

office which those of coal had performed before; a fresh supply of coal is obtained; the interstices are again filled up by the bulging of the shale, and the workings are thus suspended and renewed till the mine is finally abandoned.

I am informed that horse adits have been tried at the Great Clee Hill, in Shropshire, and failed there simply in consequence of the swelling of the argillaceous beds, which takes place to so great an extent, that a party of men is employed every night to enlarge or prop up the adits in which another party had worked during the day: without this precaution, the galleries would in a short time be closed.

Sometimes, says Williams [a], "the roof "falls down for a certain space below its "ordinary level, and squeezes the coal "much thinner, especially in the middle "of that space. These accidents are of "various dimensions, some of them not "more than two or three feet in diameter; "these are like a wart or protuberance on "the under side of the roof of the coal, and

[a] Mineral Kingdom, 2d. edit. vol. i. p. 60.

" sink into the upper side of the coal, like " the bottom of a great pot. Others are " two or three yards in diameter, and some " even thirty or forty. The large ones do " not thrust themselves into the coal so " abruptly as the small ones, but press down " gradually with a gentle swell."

Where clay alternates with limestone or silex, may not contorsions have taken place in consequence of the unequal rate at which these substances would consolidate? and will not the contorsions which are the most sudden, be found in those substances, which at the time they became contorted, were the most ductile?

IV. On the motion of the fluid from which they were deposited.

In the mica slate which occurs between Lough Mask and Lough Corrib, in Galway, the mica has a determinate direction, and its laminæ are straight, but the intervening quarz is sometimes straight, sometimes curved, and varies so materially in its direction, that what in one spot would be

supposed to be a conformable layer, exhibits in another all the characters of a vein.

Near Cherbourg, between the little cove of le Poulet and Becquet, a small village on the east of Bretteville, where beds of killas, both plane and curved, are striped by veins of quarz, I could not fail to observe that the curvatures were most sensible in those parts in which the quarz was most abundant.

Mr. Hutchinson [a], speaking of inflexions in killas, remarks that this substance was probably thrown into that irregular and unnatural posture by some irregular agitation of the water; in corroboration of which he states that the straight slates are finer and firmer than those which are inflected.

Mr. Calcot [b] pursues this idea further.

In the veins of some sorts of stone, he says, it is common to observe a great variety of matter in the greatest variety of forms and directions; in some part, matter that was lighter than the neighbouring, pressed down below the place due to its specific gravity, and afterwards elevated to a consi-

[a] Hutchinson's Works, vol. xii. p. 333.

[b] On the Deluge, p. 263.

derable height, till at last, meeting with matter that was heavier, and making its way downwards, the whole shall be curved by the ascent of the one and the descent of the other into a vast variety of arches, consisting of the finest and most delicate lines; in other parts you may see streaks or seams of different substances proceeding on, as it were, horizontally, in nearly straight lines, till they have been met and opposed by other matter in a contrary direction, and at the point of conflux both species of matter turned back and deflected in all the variety of wave-like dispositions that can well be imagined to have happened in two streams of water meeting each other in opposite currents: in short you may see all the diversities of forms in the solid, that any kind of agitation in a fluid could display.

But the author who has expressed himself most eloquently in favor of this opinion is M. Ramond.[a]

"Will any man attempt," says he, "to "explain the disorder which prevails in the "Pyrenees, by supposing the beds to have "been regularly deposited in the first in-

[a] Journal de Physique, vol. 53. p. 139.

" stance, and shifted afterwards by sub-
" sidences, shocks, convulsions? Sure I
" am, that nature did not so operate at the
" Pic d'Eredlitz, where trap, petrosilex, &c.
" wind in and out among plane strata of
" lime-stone — no, nor at the Pic de Midi,
" where regular beds of massive granite,
" containing beds of limestone no less re-
" gular, are traversed by whimsical creepers
" of horn-stone, gneiss, and even granite,
" which have wandered away from the main
" body of that substance. By what mira-
" culous influence did the limestone of
" Eredlitz continue plane, amid the violent
" concussion by which the siliceous veins
" were injected into it? These creepers, if
" I may call them so, at the Pic du Midi,
" what external force could so contort them,
" naturally protected as they are between two
" walls of granite? And then the granite,
" which must have acquired all the hard-
" ness it has at the moment of its crystalliz-
" ation, how did it contrive to insinuate itself
" with impunity into the intermediate lime-
" stone and to wind about there with all the
" pliability and suppleness of wax? What
" convulsions, what subsidences marvellously

" combined, sparing the surface of the rocks
" to rage more furiously within them, gave
" to the constituent parts of the marble of
" Estaubé that rotatory motion to which we
" find nothing at all similar in the entire
" mass, save only a moderate curvature. Is a
" crash, or a blow, sufficient to explain, not
" only the undulations of the limestone of
" Sers, but also the veins that traverse it?
" A stratum may get bent by sliding over
" another stratum — be it so: the play of
" crystallization, the accident of shrinking,
" may produce inflexions in heterogeneous
" rocks. I will not dispute even that; but
" that either of these causes, or both of
" them, however modified, could pro-
" duce this great movement, preserving
" the harmony of the whole, yet spreading
" disorder through all the parts, is a doc-
" trine contradicted by the disposition and
" nature of the ingredients, by the structure
" of the masses, by a comparison of the
" facts, and by the aspect of the spot."

" Here are no beds which any one can
" suspect of having been once regularly
" horizontal, continuous, and of equal thick-

" ness throughout. The compact limes-
" tones, the semi-argillaceous marbles, and
" slates of the mountains of Estaubé, the
" sandy lime-stones, the brecchias and grits
" of Mont-Perdu, seem to have been dri-
" ven against one another by opposite
" forces, which, at the point of contact,
" have shivered them into short, irregular,
" tortuous veins, the entanglement of which
" forms the intervening masses.

" Figure to yourself a number of viscid
" liquors, differently coloured, spreading
" themselves in whirling laminæ, in the
" vessel into which they are poured; watch
" a thick column of smoak floating in the
" air; you will then have before you an
" image of the confusion which prevails in
" these rocks; perhaps an explanation of
" it. While the waters were depositing
" the secondary strata, impetuous currents
" from the south disturbed this process, by
" bringing in a quantity of mud, sand, and
" rubbish; the struggle of the two con-
" flicting masses, the repeated assaults of
" the one, the persevering resistance of
" the other,— this is the idea naturally sug-

" gested, on contemplating the contorted
" veins in these rocks ; 'tis a sea consoli-
" dated in a storm, the violence of which,
" may still be seen in the petrified waves."

The undulating furrows in sand, upon the sea shore, are obviously occasioned by the unequal advance of the waves ; the incrustation upon the baths of Baiæ, exhibits similar wavings, derived from the same cause. To this cause, perhaps, we may attribute the wavings of alabaster, and of the primitive shisti.

Dr. Pacard[a], who made a very interesting series of experiments to explain the phenomena of stratification, shews, that curved strata may be artificially produced, by merely throwing into a tub of water, earths of different degrees of fineness, taking care that the last put in shall be the coarsest and heaviest.

At Ashford[b], the strata of limestone shale, are, in one place, flat and regular,

[a] Journal de Physique, vol. xviii. p. 187.
[b] Agricult. Survey of Derbyshire, vol. i. p. 331.

and at a short distance you find, without any apparent cause, the most contorted strata that can be seen.

The remarkable curve of some beds of chalk at Handfast-point, in the Isle of Purbeck, figured and described by Mr. Webster, in the work of Sir Henry Englefield, is an instance of the same kind.

Mr. Jameson[a] states, that clay-slate is sometimes waved even in veins.

V. The last cause which we have to consider, is a disposition on the part of the materials, to conform to the shape of the ground on which they are deposited; a disposition of the cast, to take the form of the mould.

Mr. Playfair[b] supposes, that curved strata preserve a constant equality of thickness and distance among the component laminæ; but we are informed, by the author of the Article, Argyleshire, in the

[a] Jameson's Mineralogy, edit. 1. vol. iii. p. 351.

[b] Illustr. p. 232.

Encyclopædia Britannica, that, in that country where the strata consist chiefly of limestone, with few or very thin strata of slate intervening, the thickness of a stratum is frequently five or six times greater at the summit of the wave, and at the hollow where it begins ascending to form the next wave, than at the immediate point where the contrary flexure takes place.

Such, I believe, will be found to be the case almost invariably in masses or strata, which are said, in Wernerian language, to be mantle-shaped, shield-shaped, saddle-shaped, basin-shaped, trough-shaped; I say almost invariably, because, in an analogous instance, that of agates, the force of attraction seems to have completely overpowered that of gravity, and the thickness of the laminæ in different places affords no criterion of their position; it will happen almost invariably, in these cases, that the masses will not be respectively parallel, the lower surface of each will follow the inequalities of the

mould, and the upper surface, in proportion as it is further removed from this, will become more and more horizontal.

Dr. Pacard * observed at the quarries at Belleville, that where one arch pointed upwards and another downwards, the strata, thus deprived of their parallelism, left an oval space, either open or filled, with extraneous matter.

In the neck of land situate between Lough Mask and Lough Corrib, the mica-slate is more contorted the nearer it approaches the greenstone.

In the valley of Ashover the limestone and superincumbent shale make a considerable sweep in order to surmount the toadstone, where it swells out beyond its usual proportions. At Crich, in the same county, where there is another protuberance of the toadstone, the "strata" of limestone rise with a moderate inclination, till it attains the western brow of the cliff, then become vertical for about 600 feet, and then nearly

* Journal de Physique, vol. xviii. p. 185.

horizontal. Notwithstanding these sudden changes of position, no trace is to be observed of fracture or dislocation.

At Dunraven, the strata of lias are folded in like manner over a rock of mountain limestone.

It is asked by Mr. Playfair if the curvature of the strata arose from the irregularity of the bottom on which they were deposited, why is it in one dimension only, and not in every direction, like that of hills or valleys, or the actual surface of the earth? Let us ascertain the fact before we endeavour to explain it. Williams, as if anticipating an objection not made till after his death, expressly tells us, that the curvatures which he describes, resemble those parallel ridges and vallies which diversify the face of a country.

According to Lehman[a], most of the secondary strata present hollows or depressions; those observed in the neighbour-

[a] Lehman's Flötz Gebirge, p. 137.

hood of Ellesmere have been supposed to possess characters peculiar to the sandstone in which they occur; and beds of gypsum are particularly noticed by the Freyberg school on account of the funnel-shaped hollows that appear in them. Some naturalists affirm that all coal-measures are deposited in troughs and basins, and dip inwards to a common point.

Strata occupying basins I have generally observed to be most disturbed where the basins suddenly contract, as the coal-measures of Pembrokeshire. Professor Raumer's Memoir furnishes me with a similar example at Flinsberg and Harrachsdorf in Silesia.

To conclude, then, let me ask, Where a rock is *stratified*, is it necessarily bounded by parallel surfaces? if so, let us hear no more of mantle-shaped, saddle-shaped, shield-shaped, fan-shaped, basin-shaped, trough-shaped stratification.

Are its surfaces necessarily parallel to those of the adjoining rock? if so, let us hear no more of unconformable and overlying stratification.

Is it sufficient that parallelism shall be found in a portion of the rock? Let us never hear of substances being unstratified. Or must it extend through the entire mass? Let us hear no more of strata.

The laminæ of flagstone, the folia of slate, are these strata? Are laminæ, four hundred yards thick, strata? Is there any assignable limit to their thickness or tenuity?

When one set of parallel planes crosses another, are both sets to be called strata, or neither, or only one of them? If one only, by what rule are we to be guided in distinguishing the real from the counterfeit?

Must the beds be so arranged as to convey to the observer the idea of deposition alternately suspended and renewed? If this is not necessary, how is the parallelism derived from stratification, to be distinguished from parallelism resulting from

other causes? and of what use is it to know whether a substance is stratified or not? If it is necessary, where two observers have imbibed contrary impressions, how shall we determine which of the two is right?

Let him who can answer these questions rest assured that he has a distinct idea of stratification.

ESSAY II.

ON THE FIGURE OF THE EARTH.

THE figure which the earth actually presents, is called its real figure; its statical is that which it would present if level with the surface of the sea.

ON THE STATICAL FIGURE OF THE EARTH.

Let the earth be supposed fluid to a certain depth; then the statical figure which it would assume, in consequence of rotation upon its axis, would be that of a spheroid flattened at the poles.

Such, or nearly such, being the figure which it has assumed, we have good reason to believe from this circumstance alone, that the earth has been more or less fluid to a certain depth; and on examining the

substances of which its crust is composed, we find in confirmation of that belief, evident marks that these substances have all existed at some period or other in a soft or fluid state, and most of them in a state of aqueous solution or suspension. Whence so large a supply of water can have been obtained as would be necessary to render fluid the entire surface of the globe, what can have become of it when obtained, are indeed questions far beyond the limit of our knowledge, if not beyond that of rational conjecture; but in Geology, as in all other sciences, it will happen continually, that we are unable to discredit what we are unable to explain. Before we yield or refuse assent to any proposition, we must sum up probabilities and improbabilities on both sides, and strike a balance. Now in the case before us, it is less extraordinary that water should have stood in some former period at a height exceeding that of our highest mountains, than that crystals should have been formed without a solvent,—strata without a sediment or precipitate,—that consolidation should have taken place with-

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out the union of parts, — desiccation without moisture, — that fishes innumerable should have lived without water, — and gravel have been rounded without attrition. Almost every writer, therefore, who has touched upon this subject, admits the original fluidity of the earth; — not so, however, the Huttonians; they recognize in nature no trace either of a beginning or an end; they know of nothing original.

Omnia mortali mutantur lege creata,
At manet incolumis mundus suaque omnia servat;
Quæ nec longa dies auget, minuitve senectus,
Nec motus puncto currit, cursusque fatigat.
Idem semper erit, quoniam semper fuit idem:
Non alium videre patres, aliumve minores
Aspicient; deus est qui non mutatur in ævum.
Manilius Astr. i. 515.

Accordingly an ingenious, but in my opinion ineffectual attempt, has been made by one of the most eminent writers of that school, to deduce the statical figure of the earth from the gradual changes which occur in its actual figure. These changes he attributes to two causes; one the continual wear and tear of the surface; the other the

production of new lands, volcanic or not volcanic, thrown up from the bottom of the sea at indefinite periods, to uncertain altitudes, by heat how excited, how supported, whence gifted on a sudden with explosive power, we are not informed, and thrown up always in the absence of witnesses. These two causes are said to counterbalance each other, and we are not prepared, therefore, to anticipate from them any effect. But we are told, that the general tendency to produce in the earth a spheroidal figure, "may" still remain, and more [a], "may" be done by every revolution, to bring about the attainment of that figure, than to cause a deviation from it: to that figure, therefore, the earth by a mere change of tense, "will" continually approach. — Continually approach? then in time it will acquire it. Mr. Playfair entertains a different opinion; upon what founded he does not inform us, but contents himself with observing, that the Huttonian theory affords, what no theory had before done, a satisfactory explanation of the statical figure of the earth.

[a] Illustrations, p. 504.

ON THE REAL FIGURE OF THE EARTH.

The actual figure of the earth is diversified by eminences, depressions, and plains of uncertain extent and elevation.

Compared with the solid contents of our planet, these irregularities are insignificant, of no more moment, to use the expressive language of Seneca, than particles of dust on the surface of an artificial globe. It is always useful to enlarge our ideas of nature by reflecting on the comparative littleness of those objects which we are accustomed to consider the most sublime. The interest, however, which mountain and valley are calculated to excite in us, depending not upon their relations to our planet, but upon their relations to our species, is little affected by any comparison that may be instituted between their magnitude and that of the world at large.

From the internal evidence which the complexion of our earth affords, I propose to trace its inequalities of surface, first to their proximate cause, afterwards to those causes which are more remote.

ON THE PROXIMATE CAUSE OF THE INEQUALITIES NOW SUBSISTING ON THE SURFACE OF THE EARTH.

Some changes are now going on, and ever have been since history began, from recent volcanoes, coral reefs, dunes, and calcareous concretions. These, however, which are much less considerable in amount than we are at first disposed to represent them, have been so ably pourtrayed by M. Cuvier, in his well known preliminary dissertation, that it is unnecessary to do more than declare my entire concurrence in the view which he has taken of this part of the subject.

The interstices between mountains and hills, have been produced, for the most part[a], by the removal of matter which formerly occupied them.

In countries where the strata are horizontal, opposite hills having the same elevation, generally consist of the same sub-

[a] The rule does not apply to volcanic countries, sand dunes, and coral reefs.

stances; the beds found on the heights are wanting in the bottom of the valley; those which lie beneath these beds in geological order, are not wanting. Sometimes the lower half of a bed is found in the bottom of a valley, the upper half only on its side; followed to the head of a comb, the opposite strata approach, unite. This correspondence cannot escape the most careless observer in those vallies, the walls of which are precipitous, and at no great distance from each other. It often exists, however, though not so strikingly displayed, in wider vallies, where the opposite banks are separated by large rivers and arms of the sea.

On the opposite sides of the Thames, the gravel and sands of Blackheath correspond with those of Epping; and the clays of Hampstead, Highgate, and Harrow, with those of Richmond, Wimbledon, and Sydenham. In Derbyshire, and Yorkshire, we find numerous insulated summits of millstone grit, incumbent on a plain, consisting of mountain limestone. The chalk which prevails on both sides the English channel,

and extends to Flamborough Head, recurs in the islands of Jutland, Zealand, and Rugen. That of Dorsetshire re-appears in the Isle of Wight, and in the same extraordinary posture. The Lias, at the mouth of the Seine, is covered immediately by green sand, to the exclusion of the various clays, grits, and oolites, which generally divide them. The same irregularity happens on the opposite coast at Lyme, and at both places are discovered the remains of fossil crocodiles.

The hard white limestone and trap, found on the north coast of Antrim, are precisely the same as those of the opposite island of Rathlin. The ridge of shistus which crosses the south of Scotland, from St. Abb's head to Portpatrick, re-appears at Donaghadee, in Ireland.

The granite of Iona is found again at the south-western extremity of Mull; and that of the Land's End, in the islands of Scilly. The sienite and superincumbent killas of the Morne mountains in Ireland, are identical with those which compose the Lowren and Criffel mountains in Scotland.

Buffon[a] informs us, "that the Maldiva "islands, which, when taken together, "extend about 200 leagues in length, are "divided into thirteen clusters: each is "surrounded with a chain of rocks of the "same stone, and there are only three or "four small and dangerous openings, by "which they can be approached; they are "all placed in a line, with their ends to "each other, and appear evidently to have "been a long mountain crowned with rock."

The Bahama Islands all consist of the same limestone as the nearest point of the mainland, and the resemblance which M. Herminier[b] has observed in the mineral productions of the Antilles and those of the adjacent continent, induces him to suppose that these islands have been continuous, and the gulph of Mexico a Mediterranean sea.

The bed of the Adriatic[c] is of shell marble, the same as that of the mountains on both sides. The strata of Syracuse correspond with those of Malta, and the strata

[a] Buffon, Smellie's Translation, vol. i. p. 177.
[b] Journal de Physique.
[c] Donati, Journal de Physique, vol. ii. p. 593.

of Malta with those of Gozo. The same striking resemblance in the products of opposite islands has been observed in the Grecian Archipelago.

What is the natural inference to be drawn from these several circumstances of agreement? "If a person were to see the broken "walls of a palace or castle that had been "in part demolished, he would trace the "lines in which the walls had been carried, "and in thought, fill up the breaches, and "reunite the whole. In the same man-"ner," says Mr. Catcott[a], "when we view "the naked ends or broken edges of strata "on one side of a valley, and compare "them with their correspondent ends on "the other, we cannot but perceive that "the intermediate space was once filled up, "and the strata continued from mountain "to mountain."

Strange, that some writers who admit the original continuity of all other rocks, however discontinuous we now find them, should so lose sight of analogy, when they

[a] Treatise on the Deluge, p. 163.

speak of basaltic rocks, as to imagine the occurrence of these in insulated hummocks, a remarkable phenomenon, out of the common course of nature, and to be explained only by the capricious interference of their favourite idol Vulcan or Pluto!

Another point in which this agreement may be observed, is in mineral veins. I know not of any instance in which the course of a vein or dyke has been cut off by a valley, so as not to recur on the opposite side.

It is observed by Dolomieu[a], that the same veins are distinguishable on either side of the valleys situate near Monte Rosa.

At Killarney a lead mine is worked under the lake: at Clontarf, near Dublin, beneath the Bay: at the Wherry Mine, near Penzance, and several others on the coast between Cape Cornwall and St. Ives, for tin and copper, the workings for tin and copper have been carried under the sea.

That the strata which constitute the coast of Antrim, once extended further than they

[a] Journal des Mines, tom. vii. p. 424.

do at present, is proved by the basaltic[a] dykes which project into the sea. Near Carrickfergus, many of the points or headlands, are formed by dykes of the same nature, which certainly cannot have always terminated where they do at present.

This correspondence may be observed also in the nature of the soil, gravel, and bowlder stones.

"At the back of the rocks in Malta, and "in clefts of mountains in Gozo, are heaps "of grey[b] clay, evidently no native of the "soil:" how could the clay have got over the high craggy rocks of those two islands, unless they had been formerly joined to a higher land?

The blocks of granite found at Staffa, at Rugen, and Poel in the Baltic, seem derived from the adjacent land. The Verde di Corsica, the slate, which contains octaedral crystals of iron ore, and other substances, found in the state of pebbles on the coast

[a] The mile-stone, the dykes of Portsea, and Pontauban.

[b] Boisgelin's History of Malta.

of Liguria, have been referred, with a high degree of probability, to adjacent islands.

In vain did M. de Luc[a] object that these coincidences on the opposite sides of valleys are not found universally; the theory, he rejected, does not require that they should be: it requires only that two places separated by a valley, should be as similar to one another as they might reasonably have been expected to be, had no valley intervened. Where the interval is large, a change may easily take place in the nature, thickness, or position of the strata, and from the unequal hardness and destructibility which we should naturally expect in different rocks, vallies often extend along the lines of junction.

In the Orkney Islands may be seen a primitive rock similar to one found at the nearest point of Norway, in contact with a secondary rock similar to one found at the nearest point in Scotland. Had the interval of sea occurred in any other spot, the contact would have been concealed: the opposite coasts would not have been si-

[a] Travels in the North of Europe, p. 10.

milar; but the doctrine of their original union, though unsupported, in that case, by one of the principal arguments by which it is now supported, would obviously have then been neither more nor less true than it is at present.

It is very possible, however, that this argument, founded on the resemblances of distant objects, may be strained by incautious reasoners beyond its just limits. There is a striking resemblance between the simple minerals of Norway and those of the United States of America: but this resemblance, unsupported by other evidence, would hardly entitle us to infer an original union of countries so remote from each other; we are not at liberty to conclude that the Trap of Scotland has ever been connected with that of Bombay, or the coal of Durham with that of New Holland.

At Heidelberg, they say there was once a subterranean communication between a ruined castle which commands the town, and another castle, the site of which is on the summit of a mountain equally elevated on the opposite side of the river. The say-

ing has probably originated in the circumstance of both these castles having a subterraneous passage, now blocked up, in the sand stone on which they are built: as, however, under this sand stone the strata are composed of granite, and the river runs on granite, he who trusts to physical evidence rather than traditional, may safely pronounce this communication fabulous.

Pumice is found on both sides the Rhine, at Andernach: Tarras on both sides the Brohl: Porphyritic lavas on both sides the Gran, in Hungary. Volcanic products occur in many islands in the Mediterranean; yet we are by no means to assume that these are remnants of beds once united.

From the discovery of elephants' bones in the two hemispheres, Buffon hastily inferred that they were once continuous.

It is not only in the nature of the strata that this correspondence in the opposite sides of a valley is observable; it is observable also in their position.

"The vallies of the Jura," says Saussure[a],

[a] Voyages, § 343.

" are often screened by two chains of moun-
" tains, the escarpments of which face one
" another."

At the Dent de Vaulion, the beds dip rapidly to the north; in the opposite valley to the south. At Besançon, the beds on each side the valley of the Doux, are so disposed as if they still wanted to lean against each other. The strata of the North and South Downs dip opposite ways. Dorsetshire and the Isle of Wight furnish perhaps more striking examples of similarity in the posture of strata, their posture being very uncommon.

Between Fast Castle [a] and Eyemouth in Berwickshire, may be seen segments of circles in the convoluted strata, the remaining part of the circles having been apparently carried away by the cause, whatever it may have been, which produced the indentations of the coast.

It is obvious, that correspondence of dip at two points can afford no presumption that the rocks which exhibit it have been

[a] Trans. of R. Soc. Edin. vol. vii. p. 81.

united, if in the intervening space we find a different dip. On the other hand, unconformity of posture does not prove the original absence of continuity, since varieties of dip occur in uninterrupted strata.

The probability of two opposite cliffs, coasts, &c. being portions of a rock originally continuous, will be greater or less, as the points are more or less numerous in which the resemblance between them can be established. A correspondence in one or two respects proves but little; it may be the effect of accident; but a perfectcorrespondence throughout renders probability almost certain. He must be a determined sceptic who can doubt the pristine connexion of the Isles of Re, Aix [a], and Oleron, on the western coast of Bretagny, or that of the several Antilles [b], if, as it is stated, the same rocks, with the same grain and fossils, are found in each of them, and the coasts and hills in all are extended in the same direction.

[a] l'Encyclopedie Géographie Physique, tom. ii. p. 864.

[b] Ibid. tom. ii. p. 666.

That vallies have been formed by the partial excavation of a mass originally continuous, is further evinced by the fragments generally dispersed over the surface of the earth in the state of bowlder stones, gravel, sand, and other substances, comprehended under the general name of alluvial deposits. These deposits may often be traced to the spot from whence they were originally derived.

At a stream work near Roach, in Cornwall, are found crystals of tin so large, that it became an object to follow them to their source, and the miners have discovered the parent vein.

Huge blocks of Granite are scattered over the plains of Cheshire, Shropshire, Staffordshire, &c. The bed which supplied them may be seen in the Cambrian hills. As this bed, at different places, presents more or less variety in the proportion or aspect of its ingredients, a correspondent variety is observable in the distant insulated blocks, and thus are we enabled to ascertain almost the exact spot from which they have been respectively detached, and the

precise route they took in coming to the place which they now occupy.

The Granite blocks on Shap Common may be traced to Westsleddale, those of Kirkby Lonsdale to Burrodale Crag, and those of Kendal to the neighbourhood of High-borough bridge.

With these are found, occasionally, blocks of Greenstone derived from the same district.

In Shalkbeck, Cumberland, the masses which are altogether different from the Granite of the Lakes, may be identified with that of the Criffel Mountain in Dumfries-shire.

In Friesland are low hills, composed of bowlders of Granite, Basalt, Lava, Serpentine, Quarz, and different shisti, accompanying the Dunes which stretch from Zutphen to Arnheim. M. Desmarets [a] has traced these substances to the mountains on the Rhine.

The Granite blocks so extensively dispersed over the North of Germany, have

[a] Encycl. Geog. Physique, tom. ii. p. 469.

been followed by Von Buch[a], Hausman[b], &c. to their birth-place, in Norway and Finland.

Those dispersed over Bavaria, Franconia, and Swabia, have been identified by Count Razomowski, with rocks belonging to the mountains of Moravia, Bohemia, and Lower Austria.

As early as the year 1740, Ehrhart[c] had traced to the Tyrol, many of the blocks found in the country situate between the Alps and the Danube. The Granite blocks which lie upon mountains of secondary Limestone, near Gallis, Ostago, Feltrino, Campo de Rovere, and between Astico and the Adige, are likewise recognized by Arduino[d] as belonging to the mountains of the Tyrol.

[a] Geologische Beobachtungen vol. i. p. 19. Travels in Norway, Black's Translation, p. 14. Mem. Berlin Acad. from 1804 to 1811.

[b] Hausman's Nord-Deutsche Beiträge. See l'Encycl. Geog. Physique, vol. i. p. 239.

[c] Philosophical Transactions, 1740.

[d] l'Encycl. Geog. Physique, tom. i. p. 5. and tom. ii. p. 229.

The Granite blocks found near the Lake of Como, are referred by Amoretti[a] to the mountain of St. Gothard.

The huge insulated masses of rock which lie scattered on the mountains of Swisserland, M. Saussure,[b] and, more lately, M. Von Buch[c], have enabled us to follow with confidence to their native beds.

Of the blocks that have lodged on the Jura, the largest, and by far the most numerous, consisting of Granite, were detached, it appears, from the Pic d'Orne, situate at the extremity of Mont Blanc, above the Val de Ferret. Those on the Saleve and Voirons, belonged to the Peaks, which overhang the valley of Montjoie. Others, found near Solothurn, are known, by their peculiar grain, to have come from the Grindelwald.

The Pudding-stone in the walls of Auvernier, Colombier, Corcelles, St. Blaise on the Jorat, and in the Pays de Vaux, is too

[a] Amoretti Viaggio ai tre laghi, p. 175.

[b] Voyages dans les Alpes.

[c] Mem. of Berlin Acad. from 1804 to 1811. See also Journal de Physique, tom. xxx. p. 281.

remarkable not to be recognized immediately as that which occurs in situ in the Valorsine.

Of the blocks of Gneiss found on the Jura, some are traced to the foot of Eigers, others to the mountains between Sem Branchier and Martigny.

The blocks of black Limestone and Greywacke are traced to the mountains of Aigle, the Dent de Midi, and the Dent de Morcles.

Those of Jade and Smaragdit, occurring near Lausanne, near Maudon, and the lake of Neuchatel, to the Val de Bagne, above Sem Branchier; those of serpentine in the same neighbourhood to the Glacier of Durand.

The grey weather stones, so plentifully scattered over the southern counties of England, are evidently derived from the destruction of a rock which once lay over the chalk. Gravel may, in like manner, be traced in most instances, to the beds which supplied it. The flint gravel about London is derived from two sources at least: it is in part supplied by the attrition of flints

from the chalk, in part from a regular stratum of gravel interposed between the chalk and the London clay. Mr. Webster supposes, with reason, that this gravel may also contain, occasionally, fragments of upper strata, which formerly existed in this island and have been destroyed.''

No less true than striking is the remark of the author of a work entitled Contemplations of Nature, that there is no picking up a pebble by the brook-side, but we find all nature in connexion with it.

The resemblances hitherto adduced as occurring on the opposite side of vallies have been brought forward only to prove that those intervals which we now find between mountains, have not been from the beginning; that vallies owe their origin to the removal of matter which once occupied them; that there was a time, when, to use a memorable expression of Sir J. Hall, vallies were not only submarine, but subterranean. Another coincidence, still more

remarkable, will not merely corroborate the arguments already advanced, but evince further, that the excavating agent was running water.

The disposition of ground often resembles works in fortification, the mountains representing bastions, the vallies covered ways. If we travel along a valley which runs north and south, the mountains on our right project eastwards, those on our left westwards; and salient and re-entering angles are to be seen on either side in alternate order, so that the one shall be invariably opposed to the other.

After having crossed the Alps thirty times, the Appenines twice, and having, by repeated excursions familiarized himself with the entire chain of the Jura, Bourguet published this doctrine in 1729, and expressed surprize that a phenomenon so obvious and striking should have remained till then unobserved. Fully aware of the importance of his discovery, M. Bourguet entitles it a Key to the Theory of the Earth.

His doctrine does not appear, however,

to have received from the public the attention it deserved, till illustrated and enforced by the eloquence of Buffon.

The windings in the channels of rivers, says this celebrated naturalist, "have corresponding angles on their opposite banks, "and as mountains and hills which may be "regarded as the banks of valleys, have "likewise sinuosities with corresponding "angles, this circumstance seems to demonstrate, that vallies have been formed in "the same manner as the channels of rivers."

Is this rule capable of being generalized? The author whom I have just quoted, observed, that the correspondence held equally good, whether the mountains were separated by an extensive plain, or narrow valley. He found corresponding angles, like those of inland mountains, on the opposite coasts of the straights of Magellan; and Tournefort, on the opposite sides of the Hellespont; but Humboldt[a] has given to this doctrine much greater extension: He says "the salient and re-entering

[a] Journal de Physique, tom. liii. p. 32.

" angles of Europe, Africa, and America,
" evince, that the old and new Continents
" have been divided by the action of water,
" and that the Atlantic is a valley so exca-
" vated."

In looking at a map of the world, it is not difficult certainly to discover occasional appearances of corresponding bays and promontories. The coast of Guinea forms, if you please, a salient, and that of Congo, a re-entering angle, commensurate with the re-entering angle of Mexico, and the salient angle of Brazil; but does the correspondence extend along the whole line of continents, or is it of such rare occurrence, that the rule is lost in the exceptions? If this reciprocity of form, did, indeed, pervade the coasts of opposite hemispheres, we should have reason to doubt, whether it might not have arisen in other places, from a different cause than is now assigned to it. Upon what do the sinuosities of running water depend? upon its oscillation; upon its falling away alternately from one side to the other, in consequence of obstacles; upon its tendency to

move from parts that resist more, to parts that resist less. We are not, therefore, to expect traces of such a motion on the opposite coasts of the Old World and the New, unless we suppose that a body of water, having power to scoop out the bed of the Atlantic, has met with some impediment sufficient to divert its stream from the coasts of Europe and Asia, to that of America. Accordingly, so far from being able to discover alternate and opposite angles along the shores of the Ocean, we cannot discover them along the shores of the Mediterranean, the Baltic, the Red Sea, the English or Bristol Channel, nor even along the banks of the inland lakes of Windermere, Loch Lomond, or Killarney.

Other writers deny the fact to be so general, even as Bourguet represented it to be; in the vallies of the infant Rhine, Rhone, and Reuss, they have searched for these appearances in vain, and, therefore, suppose them confined to secondary districts: but it is not true that they belong more to secondary districts than primary, nor if true, would the instances adduced

affect the general reasoning. Mountain torrents scarcely oscillate ; they either tear and carry off the obstacles they encounter, or shoot headlong over them. It is not, therefore, amid the rapids of Alpine countries that we should expect sinuosity, if the theory of aqueous excavation were true ; and its truth is the more probable, from our not finding sinuosity in such situations. The straightness of the channel of a river depends in great measure on the rapidity of its stream, the curves being few and sharp, where the declivity is steep ; numerous, easy, and swelling, where it is gentle. If, in primitive districts situate on low ground, traces of sinuosity are not discernible, while they are distinct in secondary rocks situate at a higher level, what other inference can be drawn, than that some substances have yielded from their softness to those impressions, which others by their hardness have been enabled to resist ?

The savages[a] in North America are said to be so far advanced in natural science as

[a] Buffon, Smellie's Translation, vol. i. p. 257.

to form pretty accurate computations of their distance from the sea, by observing the courses of rivers: if a river runs nearly straight, for fifteen or twenty leagues, they know themselves to be a great way from the coast: if there are many sinuosities, they conclude that they are not far from the sea.

Valleys have a tendency to increase gradually in breadth as they descend, modified however by two disturbing causes, which I shall presently have occasion to notice. A necessary consequence of this tendency is the gradual tapering of promontories. The wedgelike form, so strikingly exemplified in the peninsulas of Africa and South America, is found for the most part in individual hills and mountains, the broad end fronting the head[a] of the valley.

Now in regard to disturbing causes:-

The breadth of valleys depends in some measure on the comparative hardness of the substances which bound them. The

[a] Transactions R. S. Edin. vol. vii. p. 170.

great vallies of Hungary and Bohemia consist chiefly of soft secondary rocks ; but at the lower extremity these vallies contract into gorges, because in that part of their course they are bounded by primary rocks.

Again, the size and direction of a valley change as often as it is joined by lateral vallies, and the amount of the change so produced varies in proportion to the size of the valley that produces it, and the angle at which the two meet.

The larger the valley, the more even is in general the surface of its bottom, this evenness resulting from the accumulation of debris.

From all these considerations, I think we are justified in concluding that vallies have in general been formed by the action of running water ; and consequently, that mountains in general are not the effect of volcanoes*, as Lazzaro Moro, Stenon,

* For a more detailed refutation of these opinions vide Deluc's Lettres Phys. Disc. 47. — Catcot on the Deluge, p. 178. — Bertrand Nouveaux Principes de Geologie p. 3 and 35, and Cuvier's Discours Preliminaire.

Sprengseysen, and Kruger supposed; nor of earthquakes, according to the doctrine of Ray and Hook; nor accumulations of sand or mud brought together by submarine currents, as was imagined by Le Cat, Buffon, Le Maillet, and the Bishop of Clogher; nor crystalline shoots, as Rouille and La Metherie represent them; nor remnants of subsided strata after the notion of Deluc and Hollman[a]; but the hardest and least destructible portions of the earth, as it stood at some earlier epoch.

The terms mountain and valley are relative; that, which is mountain compared with the ground beneath, is valley compared with the ground above it. The valley of the Thames at London is contained in that of which Clapham Rise forms part of the boundary on one side, and the Green Park on the other, and this again is contained in the larger valley which occupies the interval between Highgate and Sydenham. Arrived at these points we find our horizon

[a] Journal de Physique, Introd. tom. ii.

bounded by a chalk ridge still loftier. In like manner, continents are made up of successive steppes, or terraces, rising on every side from the sea to the summits of Mexico and Thibet, so that, with the exception of these, every spot upon the globe is overlooked by some other: but whether we consider the large or the small, the including valley or the included, the first member of the series or the last, the phenomena are uniform in kind, the course of the mountains being always determined by that of the valleys, the course of the valleys by that of the excavating waters.

The truth of these opinions will appear still more evident if we consider the phenomena of what are called alluvial deposits.

1. These deposits, whether found on hills or in valleys, seem to have been invariably derived from the breaking up of rocks, situate at a higher level than themselves.

2. The larger masses of the same substance, are generally found nearest to the parent rock.

Dr. Ehrhart[a] speaking of gravel in the Tyrol says, "these stones increase "in bulk from Memingen towards the "Alps, till they get to be three or four "feet in diameter; in the opposite direc- "tion they gradually decrease to the size "of coarse sand. We may collect from "Guettard[b] that a similar gradation is "found in the gravel which covers the "plains of Poland, from the Carpathian "mountains to the Baltic."

True it is, that blocks of very different sizes are sometimes found together, both on hills and plains; that in some places the small pieces are in abundance, though there are few blocks, and that in others the blocks are in abundance, though there are few of the smaller pieces.

But these seeming irregularities, referable to some local cause, only confirm the

[a] Phil. Trans. for 1740.

[b] Mem. Acad. des Sciences for 1762. Playfair's Illust. p. 382.

argument which they have been adduced to disprove[a]; for similar irregularities take place on a smaller scale, in the detritus produced on the sea-shore by the waves, and by torrents inland.

3. Those blocks or pebbles which are most distant from their native place, are composed of the hardest and most indestructible materials as Granit, Greenstone, and Quarz, Chert, Flint, and Jasper. It is in part owing to their rapid disintegration, that Basalt does not yield gravel in the vallies of Antrim, nor Chalk in the Weald of Kent and Sussex, nor Oolite more abundantly in the vales of the midland counties.

4. Substances which break into cubic or hexagonal blocks, are found at a greater distance from their native place than those which break into blocks, the angles of which are acute; this is one reason why Granit bowlders have travelled further than slate.

[a] Deluc's Travels, vol. i. p. 121.

The occurrence of these bowlder stones in Switzerland, and along the shores of the Baltic, is notorious; but the phenomenon is by no means confined to these countries. At Glenmalur, in the county of Wicklow, huge masses of Granit rest upon the mica slate. Along the vallies of the Garonne and Gave de Pau, you find granitic blocks derived from the Pyrenees; along the valleys of the Aveyron [a] and Dordogne, from the Cevennes; at Bains from the Vosges. In the department of Morbihan [b], the number of blocks is estimated at four thousand, and some of them are not less than twenty feet in height.

Near Turin [c], the calcareous hills are covered by blocks of Granit, some of them of the size of thirty cubic feet, although no mountain of that substance is found within many leagues. Gerenna, in Grenada [d], is famous for its bowlders, which suggest the idea of a shower of stones.

[a] Bertrand. Nouveaux Principes de Geologie, p. 161.
[b] Cambry, Monumens Celtiques.
[c] La Metheric, Theorie de la Terre, tom. iv. p. 417.
[d] Bowles.

The mountain of Oden Tschelonn[a], in Siberia, according to Patrin, owes its name (which in the Mogul language signifies petrified flocks) to the Granit bowlders which are found there.

La Metherie[b] says, there are none of these blocks in Asia; it is more probable that, insensible of their importance, travellers in that part of the world have passed them by unnoticed.

Near the Lake Asphaltites[c], are blocks which have been mistaken for mutilated statues.

Chardin found in the plains of Media, stones so large, that it would require at least eight men to move any one of them, and yet there is no stone, he says, of the same kind in *situ*, within a circuit of eighteen leagues. In the mountains of Arabia, near Angoura, mention is made of small pyramids, which I suppose to be bowlders. Paul Lucas[d] states their number at twenty thousand.

[a] Journal de Physique, tom. xxxix. p. 339.
[b] Theorie de la Terre, tom. iv. p. 419.
[c] Volney's Travels in Egypt.
[d] Paul Lucas, tom. i. p. 160.

Of the famous rock in Horeb, said to be that which at the touch of Moses' rod furnished water to the Israelites in the wilderness, Dr. Shaw [a] gives us the following account: "It is a block of granite marble "about six yards square, lying tottering as "it were in the middle of the valley, and "seems to have belonged to Mount Sinai, "which hangs in a variety of precipices "all over the plain." I am informed that blocks of Granit extend for more than one hundred miles on the south of Lake Huron, in North America, and appear in islands twelve miles from its margin.

Granit bowlders, therefore, are not of partial occurrence, nor is the theory tenable, which supposes those found in the North of Germany, to have slid thither upon the ice.

A late naturalist [b], who, dying in the fullness of years, left behind him a name much too respectable to prevent his errors from being contagious, advanced a very extraordinary hypothesis, to explain the

[a] Shaw's Travels, p. 352.
[b] Deluc's Geol. Tr. vol. i.

blocks so frequent on the Jura, and in Northern Germany; he supposed these blocks to have been thrown up by the expansive power of Gas, generated at the time of their formation, and to have fallen where we now find them; that is, resting upon beds of limestone and sandstone, the pedestal on which they rest unshattered. How blocks of such enormous weight and magnitude, could fall upon beds so fragile, without fracturing them, it is not easy to discover; still less, how such an event could happen before these beds were in existence; for, I suppose, no one will claim for the mountains of Jura so high an antiquity as is conceded to Mont Blanc.

It is some palliation, however, of this hypothesis, that it was constructed at a time when the imaginations of all men were so dazzled by the brilliant discoveries then making, in pneumatic chemistry, that it was almost as difficult to speculate without Gas, as to breathe without air.

The circumstance of primitive blocks resting so frequently upon secondary beds, furnishes an argument equally conclusive

against the opinion that these blocks are only the survivors[a] of a catastrophe by which the adjoining parts of the strata to which they belonged were destroyed.

These theories refuted, there remains, in explanation of the phenomena of bowlder-stones, the theory which attributes their occurrence, like that of ordinary gravel, to the action of running water.

The arguments in favour of that doctrine are, that bowlder-stones are evidently not *in situ*; that they are, for the most part, traceable to the parent rock, which, however distant, is always at a higher level than themselves; that they often rest upon beds either secondary or alluvial; and lastly, that the upper surface of rocks protected by soil, is in many cases so furrowed[b] as to resemble a wet road, along which a number of heavy and irregular bodies have been dragged, these furrows ge-

[a] Bertrand's Geologie, ed. i. p. 160. et seq.

[b] Vide Transactions R. S. Edin. vol. vii. p. 139. where this circumstance is described at length and exemplified.

nerally agreeing, in parallelism, both with one another, and with the ridges and large features of the district.

On the other side, it is objected, first, that between [a] the supposed parent rock and the bowlder-stones, there is often an interval in which none of these bodies are seen; secondly, that vallies, rivers, lakes, arms of the sea, intervene between the bowlder-stones and rock with which they are supposed to have been originally connected; thirdly, that these stones are often much too large to have been swept along by the action of water.

The first of these objections, however, proceeds on an assumption which I apprehend to be altogether gratuitous, since it has not been shown, that, had bowlder-stones been so transported, there would have been no vacant intervals, or that their distribution would have been in any respect different from what it actually is.

The second objection does not apply to bowlder-stones having been transported by the action of running water, but simply to

[a] Deluc's Geological Travels, vol. i.

their having been so transported at a period subsequent to the formation of vallies, rivers, lakes, and arms of the sea.

To estimate the value of the third objection, it is necessary to consider separately what is the magnitude of the largest of these blocks, and what power running water possesses, of removing them from one spot to another.

The dimensions of the block, out of which was hewn the pedestal of the statue of Peter the Great, after being somewhat reduced, were, length at the base 42 feet; at the top 36 feet; breadth 21 feet; height 17 feet: Its weight exceeded 1500 tons.

The Needle[a] Mountain, in Dauphiné, said to be a Bowlder, is one thousand paces in circumference at the bottom, and two thousand at the top. At Pierre à Bot[b], above the lake of Neufchatel, is a Granite block forty feet high, fifty long, twenty broad, weighing thirty-eight thousand cwt. The block called Pierre à Martin[c], measures

[a] Hist. de l'Academie des Sciences, for 1700, p. 4.
[b] Memoirs of the Berlin Academy, from 1804 to 1811.
[c] Transactions of the R. S. Edin. vol. vii. p. 142.

ten thousand two hundred and ninety-six cubic feet.

In what manner can running waters have acted, so as to set in motion and transport to very considerable distances masses of such prodigious dimensions?

The author [a], by whom the theory of Dr. Hutton has been so ably illustrated and defended, always disposed to cut the knot, rather than call upon the gods to untie it, has referred this extraordinary phenomenon to the operation of ordinary causes. After noticing the celebrated blocks scattered upon the surface of the narrow vale or glen which separates the Great from the Little Saleve, (one of them measuring about 12 hundred cubic feet,) "for my part," he says, "I have "no doubt that the Arve, which is still at "no great distance, when it ran on a higher "level, and in a line different from the pre- "sent, aided by the glaciers and superior ele- "vation of the mountains, was an engine suf- "ficiently powerful for effecting the trans- "portation of these stones."

Another eminent disciple [b] of the same

[a] Illustrations, p. 392.

[b] Transactions R. S. Edin. vol. vii. p. 142.

school ventures upon this point to dissent from the opinions of his master. "To move "a mass of granite of even fifty or sixty "cubic feet, and to carry it a few yards, "would," he says, "require the utmost ef- "forts of the Rhone or the Arve, as they "flow near Geneva, in their highest floods; "but that such blocks could be conveyed "by one of them along its whole course, is "contrary to all experience, and still more "when we consider that these rivers are di- "vided, at their source from beneath the "Glaciers, into forty or fifty small streams. "Yet from the Glaciers these blocks must "have come; and when we take into ac- "count the magnitude of some of these gra- "nitic masses, it is clear that the task is "beyond the power of any River that flows "on the surface of the earth."

Bowles, the traveller in Spain, who bestowed much attention on this subject, thinks, that Rivers, flowing under ordinary circumstances, are incompetent to transport to any distance, not only colossal blocks, but moderately-sized gravel.

"From the singularity of their appear-

"ance," he says, "there are few pebbles "which it would be so easy to recognize, "as those in the bed of the Henares, near "St. Fernandez. If they ever moved at all, "they ought, in the course of ages, to have "found their way into the Tagus a little "way off; but there is not one of them in "the Tagus.

"At Sacedon, the Tagus is full of lime-"stone pebbles: lower down, at Aranjuez, "are none. Nobody has ever seen granite "pebbles, large or small, in the Ebro, nor "blue stones veined with white; yet the "Cinca, before it joins the Ebro, abounds "in them.

"White and red pebbles of Quarz are "found in the bed of the Noxera, which "likewise falls into the Ebro; but in the "Ebro is found nothing of the kind. The "Guadiana in different parts of its course "flows over pebbles, similar to those "found in the strata of the adjacent hills; "but those, which occur half a league up "the stream, never mix with those which "occur half a league down; and at Bada-"jos, stones of this kind, being no longer

" found in the cliffs, are no longer found
" in the river.

" At the source of the Loire are pebbles
" innumerable; lower down, at Nevers,
" only sand.

" In the Yonne river, above Sens, are
" flints in abundance; for they abound in
" the banks of the Yonne, about Joigny.
" The Yonne falls into the Seine above
" Paris; but who ever saw any of these
" flints at the Pont-neuf, or any pebble
" whatever, round or angular?

" Near the Perte du Rhone you cross
" the river of the Valorsine, which is full
" of pebbles, because the country it flows
" through is full of them. At one place,
" this river tumbles into a kind of cavern;
" If pebbles were carried down by Rivers,
" the cavern ought to contain them in
" abundance; It does not contain one. On
" my way to Geneva, I threw some stones,
" which I had marked so that I might
" know them again, into this river, just
" above its fall; and there I found them on
" my return; They had not advanced an
" inch during my absence.

"The Rhone, Garonne, and Adour rivers,
"remarkable for the quantity of pebbles
"they run over in one part of their course,
"have only sand at their mouth."

These remarks, being equally applicable to all countries, may be verified by every one in his own neighbourhood. I therefore abstain from adducing the similar instances which crowd upon my mind, when I consider what happens in our English rivers. Enough has been said to prove, that, flowing, under ordinary circumstances, over ground which is level, or nearly level, the power, which Rivers possess to propel even gravel, is so trifling as scarcely to deserve consideration. When, their stream being accelerated by the near approach of their banks, by the occasionally increasing declivity of their beds, or by the augmented volume of water afforded by heavy rains or thaws, they exhibit themselves in the form of a Torrent, it cannot be denied that they have the power of carrying, to a certain distance, the fragments which have fallen from adjacent cliffs or hills, and of fretting and rounding them by mutual attrition;

but even under these circumstances, I believe, he, who can divert his mind from the picturesque beauty of a cataract to a philosophical consideration of its effects, will be disposed to admit that the power of Rivers, when most impetuous, is considerably less than is in general apprehended. At all events it is but short-lived, and ceases with the cause.

If then we chuse to suppose that the blocks scattered so extensively over the face of the Jura chain were brought by Rivers, they must have been brought by rivers, descending with great velocity along a plane, regularly inclined to the distance of many leagues; but, supposing the inclination to be the smallest which the advocates of this theory consider capable of effecting the object, it has been clearly shown by Sir James Hall, that the summit of such an imaginary plane would be far above the level of perpetual snow, and, consequently, far above the level at which rivers can exist.

The phenomena of the blocks, which have been traced to the northern parts of Europe, are still more adverse to the hypo-

thesis of Dr. Hutton. The blocks derived from the Alps are not known to have travelled, in any instance, more than sixty miles, whereas, those which came from the mountains of Scandinavia, are said to have been traced to at least seven times that distance. Add to this their lateral, which is proportionate to their longitudinal extent; They are scattered over the Continent from Holland to Petersburg and Moscow. It is perfectly incredible, that these blocks, extending over so immense an area, and found on the opposite sides of lakes and seas, should be the waifs and estrays, either of a single River or of any number of Rivers.

If the Transportation of bowlder-stones cannot be referred to the agency of Rivers, so neither can the Excavation of Valleys.

1. Some valleys are dry, as that of Cheddar; the valley of Rocks near Linton; the Winyats near Castleton in Derbyshire. How can it be supposed that these have

been excavated by a River which has no existence?

2. If Valleys were formed by the Rivers that flow in them, how happens it, in so many instances, that the source of a river should be below the head of a valley?

3. In very many cases, where pits have been sunk to considerable depths on the banks of large rivers, the alluvial land has reached far below the level of their bed. This circumstance, to which we are to ascribe the flatness of the valleys through which they run, is altogether inconsistent, as Mr. Playfair acknowledges, with the notion, that in these places the bed of the river was excavated by the River. The action of Rivers may consist, M. Cordier observes, either in filling up or in scooping out; it cannot consist in both; if in scooping out, it has not formed the Beds of Gravel; if in filling up, it has not formed the Valleys.

4. It has been already remarked, that every valley is included in a valley still

larger. Grant that the interior has been formed by a River, can the exterior ones be ascribed to the same cause?

5. The circumstance of Rivers changing their bed, shows how little they are adapted for the purpose of excavation: if they formed a bed for themselves they could not change it.

6. To suppose that Rivers formed their own banks, is to suppose that rivers were once without banks, a supposition evidently absurd.

Buffon conceived that the inequalities on the surface of the earth had been occasioned, principally, by the motion of a Sea that once covered it; but the action of a sea on its own bed appears altogether incapable of producing such an effect; it consists in little more than shifting sand and other unconsolidated matter from those places, in which the current is strong, to those in which it is feeble or null.

At great depths, where there is no motion there can be no abrasion. Lamanon came much nearer the truth when he suggested, that submarine valleys existed before the existence of the ocean, and that currents were rather the effect of these valleys than the cause of them.

But is the Sea really incompetent to produce these effects? The striking resemblance between inland cliffs and those upon the coast affords strong presumptive evidence that both are owing to the same cause; and surely cliffs upon the coast are produced by the assaults of the Sea. He, who travels along the shores of this country, will find numerous instances of towns and churches, situate too near this destructive agent, having fallen a prey to its devastations, and many others, once inland, now no longer so, already undermined, maintaining only a precarious * existence. The concurrent testimony of nations assures us of ravages by the Sea, far more extensive than any of which we can obtain a knowledge by means of personal observation.

* See Philosophical Transactions for 1716. No. 349.

The Antiquarians of Cornwall undertake to prove from the authority of old charters and parchments, that a tract of land once extended from St. Michael's Mount to the south of Penzance; a considerable town, they tell us, standing half way between the Land's-end and the Islands of Scilly[a], has, with the circumjacent country, been overwhelmed by the waves. The Causeway of St. Patrick is pointed out to us, in another part of the coast, as the only memorial, which nature has left, of a tract of land, which connected England with her sister kingdom, till the connexion was broken off by the Sea. Conflicting tides are said to have rent England from France[b], Denmark from Sweden. It is owing to the encroachments of the Atlantic, if Strabo and Pliny are to be believed, that Spain[c] is separated from Algiers; Sicily from Apulia and Tunis; Corsica from Piedmont and Sardinia; Italy

[a] Borlase.

[b] Wallis. Buffon, Smellie's Translation, vol. i. p. 489 and 496.

[c] Pliny, l. iii. c. 8. Sicilia quondam Brutio agro cohærens, mox interfuso mari avulsa.

from Greece; Crete from the Morea; Constantinople from Asia Minor. We are told that the Chinese Islands[a], the Philippines, Borneo, Java, New Guinea, New Holland, are only Islands in consequence of the force successfully exerted by the Gulph Stream upon the once intervening country. The Maldives[b], Ceylon, and even Madagascar, are said to be mere remnants of a territory which extended formerly from the promontory of Africa to that of Hindostan; and the Atlantis of Plato, is supposed by his commentators to refer to the submersion of another territory, no less extensive, situated where the waves of the Atlantic now roll between America and Europe.

Leucada continuam veteres habuere coloni,
Nunc freta circumeunt. Zancle quoque juncta fuisse,
Dicitur Italiæ, donec confinia pontus
Abstulit, et mediâ tellurem repulit undâ.

Ovid.

Not one of these traditions, however, is entitled to the smallest credit; they are

[a] Buffon, Smellie's Translation, vol. i. p. 177.
[b] l'Encyclopedie, Geographie Physique.

unsupported by evidence, opposed to all our experience, and must be accounted the mere arbitrary speculations of men, who, anxious to explain the correspondence, which they had noticed, between distant shores, rashly ascribed to an agent, of which they did not know the power, events of which they did not know the existence.

Dr. Hutton caught the contagion of ancient and popular error; he did not fail, however, to perceive, that the depredations committed by the sea, had been greatly over-rated. "The description," he says[a], "which Polybius has given "of the Euxine, with the two opposite Bosphori, the Mæotis, the Propontis, and the port of Byzantium, are as "applicable to the state of things now, "as they were at the writing of that history. The Isthmus of Corinth is apparently the same at present as it was two "or three thousand years ago. Scylla and "Charybdis are still, as in ancient times, "rocks hazardous for coasting vessels; the "Port of Syracuse, with the Island which

[a] Theory of the Earth, vol. i. p. 190.

" forms the Greater and Lesser, and the
" Fountain of Arethusa, the water of which
" the ancients divided from the sea by a
" wall, do not seem to be altered. From
" Sicily to the coast of Egypt, there is an
" uninterrupted course of sea for one thou-
" sand miles; consequently the wind
" should bring powerful waves against
" those coasts. But on this coast of Egypt,
" we find the rock on which was built the
" famous Tower[a] of Pharos, and at the
" eastern extremity of the port Eunoste,
" the Sea Bath cut in the solid rock upon
" the shore. Both these Rocks, buffeted
" immediately by the waves of the Medi-
" terranean sea, are to all appearance the
" same at this day, as they were in ancient
" times."

" Shoals, the terror of seamen," says Dolomieu, " do not perish by time; co-
" vered perpetually by the foam of the

[a] Savary, Lettres sur l'Egypte. How slight are the changes which have taken place on the surface of our planet within the limits of historical record may be seen in l'Encycl. Geog. Phys. vol. ii. p. 561. Guettard's Memoirs, vol. iii. p. 209 & 223, and Cuvier's Discours Preliminaire.

" waves, they still maintain the conflict;
" and, after the lapse of one thousand years,
" a new shipwreck, in the same spot, attests
" how little change has taken place within
" that period. Not an instance can be
" produced of a rock, a mile in extent,
" having been washed away, during all the
" ages which have elapsed, since history
" began."

If the Sea has been supposed to overflow entire continents, it has been supposed also to abandon them.* An old saying of Pythias has been quoted, to prove that Sweden was once made up, like Denmark, of Islands; and the Caspian Sea is stated, on the authority of Strabo and Pliny, to have communicated formerly with the Baltic. These suppositions, however, like their opposites, are unworthy of credit; the Sea is no more capable of such extraordinary retreats, than of such extraordinary inroads. In violent storms, earthquakes, &c. it may

* On the retreat of the sea vid. l'Encycl. Geog. Phys. tom. iv, under the titles Meander and Palus Mæotis. Playfair's Illustrations, p. 441. Buffon, vol. i. p. 492. of Smellie's Translation.

produce consequences highly important to the property of individuals, or even the happiness of districts, but which are of no account as affecting the general structure of the globe; in its diurnal movements it fills up [a] bays with sand, and undermines promontories for a time, till at last the fallen rubbish, forming a beach, guarantees them from further destruction. It is obvious then, that agents, so circumscribed in their operations as Seas and Rivers [b], are little calculated either to effect the transportation of the bowlder-stones so often mentioned, or to produce those inequalities of mountain and valley, which the surface of our earth presents.

But, replies Mr. Playfair, "if the causes "assumed appear inadequate to the effects "produced, it is only because, in respect to "man, their movements are too slow to be "perceived. The utmost portion of the "progress to which human experience can

[a] I believe M. Deluc is the first author who entertained correct opinions on these subjects.

[b] M. La Marck, in his Hydrogeognosie, attributes to these causes the formation of mountains.

" extend, is evanescent in comparison with
" the whole, and must be regarded as the
" momentary increment of a vast progres-
" sion, circumscribed by no other limits
" than the duration of the world. Time
" performs the office of integrating the in-
" finite small parts of which the progres-
" sion is made up, it collects them into one
" scene, and produces from them an amount
" greater than any that can be assigned."

Ye Gods! annihilate, but Space and Time! was the pious but foolish and happily ineffectual exclamation of a lover who thought, that, under such circumstances, he should be happy. Ye Gods! perpetuate Time! says the Plutonist, and thinks his reasoning will be incontrovertible.

But suppose the prayer granted; suppose the Plutonist to have at command whatever time he desires; Time graduating into eternity; nay Eternity itself; what use could he make of it? what profit can a man expect from putting Zeros out to interest? what increase of weight from a Fast sufficiently prolonged?

If Seas and Rivers do not tend to produce,

within the period of human experience, any such effect as that which we are endeavouring to account for, they will evidently produce no such effect in a million of centuries. Time may complete that which is in progress; it will never complete that which can never be begun.

The Plutonists should therefore be required to make out a stronger case than they have done, before they are allowed that exemption from the Statutes of Limitation which has hitherto been granted only to the king and the church.

If Seas and Rivers are, from their feebleness, inadequate to produce the effects which have been produced by the action of water, the only remaining cause, to which these effects can be ascribed, is a Debacle or Deluge.

Of those by whom this principle is admitted, some, as Pallas, Lamanon, Sir James Hall, suppose the Debacle to have been partial; others, universal.

That the partial Inundations to which every country is more or less exposed from

Earthquakes, Water-spouts, the Melting of Snows or Glaciers, and the Interruptions produced by the Fall of Mountains, or any other cause, which rivers occasionally experience in their progress towards the sea, are inadequate to the explanation of such phenomena as we have been describing, is too obvious to be insisted upon, and, that the same objection applies to the Deluges imagined by Lamanon and Sulzer, as derived from the Overflowing of Lakes, the reader will immediately perceive, who shall propose to himself the following questions:

1. What examples have we of Lakes overflowing?

2. How could the overflowing of Lakes produce those great valleys in which the lakes themselves were situate?

3. How could Lakes exist unless there were already higher ground to embank them?

4. How could Lakes escape unless there were already lower ground to overflow?

5. Valleys take their rise on every side of mountains. Did the Lakes supposed

to have formed these valleys burst on every side?

6. What must have been the extent of that Lake, the bursting of which hollowed out the Atlantic? or rather formed a valley from Caucasus to the Andes, and from the Andes to Caucasus?

7. What must have been the power of that Lake, the bursting of which transported the granite blocks of Mont Blanc to the Jura? of Finland to Silesia?

8. What reason have we to ascribe to Lakes an origin anterior to that of seas and rivers?

Of the partial Deluges invented by Pallas and Sir James Hall, some, at least, may be considered almost universal; for, being derived from the sea, they are supposed to have over-topt the Alps[a], and the mountains of Tartary: One such Deluge would perhaps explain all the phenomena which

[a] It is possible that I here misrepresent, though unintentionally, the opinion of Sir James Hall, and that he considers the transportation of the Jura blocks to have taken place under the sea.

we want to explain; and if these authors have admitted a plurality of deluges in defiance of the recommendation of Newton, not to multiply causes unnecessarily, the reason is, that, in order to obtain their supply of water, they have had recourse to agents which left them no other choice than that of doing their work over and over again, or not doing it at all.

The cause, to which Pallas ascribes his Debacle, was the Shock experienced by the sea during those tremendous eruptions which gave rise to the Moluccas, Philippines, and other Volcanic Islands situated in the Indian Archipelago. His object in imagining this Debacle was not to explain the inequalities met with on the surface of the earth; the symmetrical construction of mountain and valley; the phenomena of bowlder-stones; the distribution of alluvial deposits equally over islands and continents; but to acount for the discovery of the Bones and Tusks of Animals inhabiting the southern latitudes in the frozen regions of Siberia. Now,

1. It is scarcely conceivable that these Bones should have travelled from the Indian [a] to the frozen ocean, a distance of 36,000 miles, without fracture or abrasion.

2. Not only insulated Bones of Elephants have been found in those northern latitudes, but their Skeletons, their very Skins and Hair. Had these animals been transported so far, though moving at the rate of 100 miles per day, still they would have been in a state of putridity long before their arrival at the places in which they are actually found.

3. With the bones of the Elephant [b] and Rhinoceros are intermixed those of the Elk, Gazelle, Horse, Ox, Buffalo, animals which inhabit northern climates.

4. Granting such eruptions to have taken place, there seems no reason why the current occasioned by them should have

[a] Journal de Physique, tom. lix. p. 244.
[b] Journal de Physique, tom. lxxx. p. 46.

taken a northern rather than a southern direction.

5. The rising of these islands could displace only a quantity of water equivalent to their bulk, a quantity altogether inadequate to the task assigned to it, that of surmounting the highest chains of Asia.

Sir James Hall was induced to adopt the theory of a Debacle, principally by a desire to account for the granite blocks dispersed over the Jura: but the cause to which he supposes that Debacle to have been owing, is stated too generally to admit of a detailed refutation. In vain does he tell us that granite is of a more recent date than the rocks with which it is asssociated; that it has been thrown up by Plutonic explosions; that continents have been elevated by similar explosions; unless he tells us also, what continent was raised at the time the Debacle took place, and where the granite is to be found the forcible ejection of which occasioned the elevation of that continent.

The universal diffusion of alluvial sand, gravel, &c. proves that, at some time or other, *an* Inundation has taken place in all countries; and the presence of similar alluvial deposits, both organic[a] and inorganic, in neighbouring or distant islands, though consisting often of substances foreign to the rocks of which the islands are respectively composed, makes it highly probable, at least, that these deposits are products of *the same* Inundation.

The universal occurrence of mountains and valleys, and the symmetry which pervades their several branches and inosculations, are further proofs, not only that *a* Deluge has swept over every part of the globe, but probably *the same* Deluge.

The next argument, which I shall advance in support of this conclusion, is founded on an almost invariable want of correspondence between the figure of the surface and the disposition of the strata or veins beneath it. Though where faults occur, the strata are tossed and turned in all directions, "it is

[a] Playfair's Illustrations, p. 461. La Metherie's Theorie de la Terre, tom. v. p. 197.

"extremely rare," says Mr. Hutchinson, "to find a lifted edge or corner of strata, "standing up above the general surface; "the faults, however large, the rise which "they occasion, being rarely discernible by "any sudden inequality of the ground: nu- "merous as cliffs, facades, mural ascents or "precipices are, very few of them are ow- "ing to faults; in general, the matter has "been carried off."*

* Mr. Hutchinson, who wrote about the middle of the last century, and of whose geological opinions I have more than once had occasion to speak with much respect, was the first author, I believe, by whom this important fact was noticed. Works, vol. xii. p. 338. It has since appeared in the works of Catcott (on the Deluge, p. 165,) Williams (Mineral Kingdom, 2d edit. vol. i. p. 338,) and Desmaret (Geographie Physique, vol. ii. p. 551;) it is noticed also by Mr. Playfair and M. Deluc, and much insisted upon by Dr. Richardson and Mr. Farey.

Buffon was sadly mistaken on this subject when he said "I have often remarked, that when the top of a "mountain is level, its strata are likewise level; but when "the top is not horizontal, the strata follow the direction "of its declivity. It has frequently been alledged that "the beds of quarries incline to the east: but in all the "chains of rocks which I have examined, I found that "these beds always follow the declivity of the hill, whe- "ther its direction be east, west, south, or north." (Smellie's Translation, vol. i. p. 172.)

Cor. 1. Hence the conformity between the direction of mountain chains and that of the strata composing them, is not, as Humboldt supposes, necessary — but only accidental.

Cor. 2. Mountains are not owing, as Deluc thought, to a subsidence of the strata which occupied their intervals.

A general view of the structure of our globe, if taken with accuracy, would tend perhaps still farther to convince us of the universal operation of this Deluge.

The southern coasts of the German ocean and Baltic, together with the north of Asia, consist of Marshes, Sands, and Alluvial plains, the rivers of which flow indiscriminately in almost every direction. In this enormous tract of *low or smooth* land, rise the Scandinavian, Uralian, English, Welsh, Scotch, and Irish Mountains, forming insulated groups: Such, under the same latitude, seems to be the structure of North America.

The central part of the old Continent exhibits a girdle of *rough or Alpine* land, extending from Portugal to China. Prodigious Mountains, many and deep Lakes characterize this tract, over a large portion of which Volcanos are distributed.

In the opposite part of the new Continent, we find the highest Mountains of America, the Gulph of Mexico, and the Volcanos of the West Indies.

South of this Alpine country, a range of sandy Desert extends over the old Continent with few interruptions, from the shores of the Atlantic Ocean to those of the Pacific. Opposite to this, on the map of America, we find the vast Plain of the Amazons and the Lanos of Mississippi.

The Mountain Range marked on the maps of Africa, under the title of Gebel el Kumir, or Mountains of the Moon, is, I believe, little better than imaginary; if such a range exists, it may perhaps be found to correspond to that which in South America appears to extend from the sources of the rivers Paraguay and Parana to Minas de la Baheia and Pernambuco.

I lay little stress on these analogies; I mention them with a view to enquiry, not to conviction; they are perhaps incorrect; they are from their nature indefinite; and I am fully aware, that whenever our ideas cease to be definite, they are apt to be fanciful.

The Direction which the waters of the Deluge observed in any particular district, may be determined by those who will employ the same diligence in exploring it, which Sir J. Hall has bestowed on the neighbourhood of Edinburgh: The method of doing this, is to examine the direction of bowlder-stones, mountains, valleys, promontories, and escarpments.

In regard to bowlder-stones enough has been said already; I will only observe here, that blocks from the Cumbrian mountains have travelled eastwards as far as Pierce Bridge, and southwards as far as Staffordshire. Chalk-Flints occur in alluvion, on the north coast of Cornwall, and even at the Land's-end. Mr. Smith supposes the inundation which swept over England, to

have come from the south-east, and though I am not aware of his reasons, I have no doubt that many may be found in support of that opinion.

The course of Mountain Ridges is as yet very imperfectly understood. Marsigli, Buache, Lehman, carried them uninterruptedly through the depths of the ocean. Continuous Ridges, like theirs, do not exist. As the banks of smaller vallies are intersected by the coombes and dales that fall into them, similar but larger and more frequent interruptions occur in the banks of those vallies which are more considerable. The Cevennes are divided from the Pyrenees by the plain in which runs the canal of Languedoc; from the Vosges, by a plain, which, extending from the Rhine to the Rhone, bifurcates near Langres. The valley of the Danube divides the Carpathian mountains from the Alps; the Riesen and Erzgebirge are detached from both: the mountain Chain of Wales is separated from

the Ocrynian by the Bristol channel; from the Cumbrian[a] by a bay of the Irish sea.

The Scandinavian mountains are bounded either by low plains, or by the sea.

What is a Chain of mountains? An elevated platform, upon which rest various summits of unequal height. Wherever the ground falls to a lower level than our platform, be its elevation what we please, there the chain or ridge ends. If we place its level above highwater mark, whatever lies beneath high-water mark can form no part of the Chain, and consequently the Chain cannot be followed across a sea. If we

[a] To the mountainous district of Cumberland, Lancashire, and Westmoreland, no name has yet been appropriated. As it occupies nearly the extent of country formerly inhabited by the Cumbri, I have ventured, on the suggestion of my friend, the Rev. Wm. Conybeare, to designate it by this term, which is short and easily understood. I am indebted to the same gentleman for the term Ocrynian, as denoting the high granitic tracts of Devonshire and Cornwall. It is used in this sense by Richard of Cirencester, and I have thought it better to revive an obsolete name than to construct a new one.

place its level below high-water mark, whatever is dry land must form a part of the Chain, and consequently the Chain cannot be followed across a continent.

Buffon made the principal Chain in the Western Hemisphere run from north to south; in the Eastern from east to west; but corrected himself in the supplement to his work, where he states, that in both Hemispheres the principal Chains run north and south, and that those which run east and west are only subordinate.

Gatterer supposes different Chains, runing in different latitudes, to cross at intervals forming a kind of net-work. According to Pallas, they radiate from a common centre. His anonymous critic takes two principal Chains parallel with the equator, the one about 50° north latitude, the other about 25° south latitude, and supposes branches to be sent off from each of these towards the equator, and towards the poles.

Our knowledge upon this subject, confined and inaccurate as it is, enables us to pro-

nounce that all these systems are erroneous.

Some modern writers have been disposed to confound chains of mountains with water-heads, and imagine that a line connecting the sources of rivers all over the globe must faithfully represent the line of greatest elevation. If the banks of rivers were in all places equally raised above their channel, it would do so; but the reverse happens continually. The environs of Prague, I believe, are at a lower level than those at Töplitz, where the Elbe effects its passage between the Erz and Riesen-gebirge. The low plain, in which Strasburg and Manheim are situate, cannot compare in height with the ridges of the Hundsruck and Westerwald. The country about Ratisbon is by no means so elevated as that between Linz and Passau; following the course of the Danube from thence, its banks are at a low level till you reach the neighbourhood of Presburg,

where it escapes through an opening left between the Alps and the Carpathian mountains. In Hungary it traverses a low plain. In Illyria it is again hemmed in by mountains.[a]

The Apalachian chain is notorious for the number of rivers by which it is intersected: equally celebrated are the gorges of the Potowmack and the Irtish.

Almost all the great rivers in Russia have their origin in low plains and morasses: there is no perceptible ridge along the water-head from Limberg to Petersburg, from Petersburg to the Oural.

This doctrine, therefore, cannot be relied upon; if it could, a ridge should be traceable from Weymouth to Fort William, from Bantry Bay to Colrain.

It has been thought that the highest mountains occupied the middle of conti-

[a] From Landrecie to Namur, the course of the Sambre is from S.W. to N.E. the general slope of the country through which it runs, being from N.E. to S.W.: similar examples might be found in the Ardennes.

nents. The highest mountains[a], however, those of Mexico and Thibet, are both at an inconsiderable distance from the sea.

It has been said that mountain chains run down the middle of peninsulas: this doctrine is another instance of hasty generalization. The greatest peninsula, that of South America, is flat on the East side, and on the West, mountainous to the very edge of the sea; the structure of Scandinavia and India is the same.

It has been thought[b] that the steep sides of mountains front the West, but the reasoning by which this proposition is supported is lax in the extreme. In England and Scandinavia the steep side of the principal ridges front the N. W.: In Italy and Dalmatia the S. W.: so that the steep side of the former is at right angles with

[a] Journal des Mines, tom. xxiv. p. 303, and 352.

[b] Dr. Stukeley, who lived in the early part of the last century, is, I believe, the first author in whose works this remark is found; see Itinerarium Curiosum, Lond. 1724, p. 3. "If we cast our eyes upon the geography of Eng-

the latter, yet both have been said to face the West.

The principal chains of Europe and Asia, *viz.* the Alps, the Pyrenees, Carpacks, Erzgebirge, the ridges of Hæmus, Taurus, Imaus, seem to have their steep sides on the South. John Reinhold Foster, well known for the extent of his travels, conceived that in general the steep side of mountains was on the South and South-east. Bergman stated, that in mountains that run North and South, the West side

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" land, we must observe that much of the Eastern shore " is flat low ground, while the Western is steep and " rocky. This holds generally true throughout the " globe, as to its great parts, continents, or islands, and " likewise particularly as to its little ones, mountains, and " plains. I mean that mountains are steep and abrupt " to the West, especially to the North-west, and have " a gentle declivity Eastward, or to the South-east, and " that plains ever descend Eastward. I wonder " very much that this remark has never been made." The subject is treated at considerable length by Tilas, in an Essay published in the Memoirs of Stockholm, vol. xxii. for 1760, and by Cronstadt, in vol. xxv. of the same work. Buffon recalled it to the attention of geologists in 1778, and Jones in 1781; see also Walker in Philosophical Magazine, vol. xxxv. and Kirwan in Nicholson's Journal, 1803.

is steepest; in those that run East and West the South.

A single glance of a good map of the mountains throughout the world, if such were to be found, would convince us that all these hypotheses must be abandoned.

Promontories, like mountains and escarpments, may be found in every direction: those of Cornwall, Carnarvonshire, Kerry, Cape St. Vincent, Cape Verd, &c. stretch Westward; in Labrador, Pernambuco, &c. they stretch Eastward; but, viewing nature on a large scale, we shall perceive, that as the great ridges, those at least of the old continent, run East and West, so the larger promontories in both tend to North and South. Had their form been determined by actually existing currents, they would have tapered away to the West. Their Southern Direction so strikingly exemplified in the three great peninsulas of South America, Africa, and India, first re-

marked by Bacon [a], has been insisted upon by Buffon and others. California, Alaschka, Greenland, Kamschatka, Scandinavia, Florida, Italy, Greece, Arcadia, Arabia [b], the Corea, are minor instances of promontories having the same direction. We are prevented by the severity of the climate from making ourselves acquainted with the form of the Northern Extremities of Greenland and America: it appears, however, by no means improbable that they may terminate in promontories directed Northwards; as is the case with Labrador, Newfoundland, Nova Zembla, Jutan, Jutland, the Samoids, the lands at the mouth of the Obi, and White Sea, Great Britain, &c.

Have not Spitzbergen, the Norwegian chain, that of Ural and Nova Zembla, the appearance of being remnants of a promontory which stretched to the North?

[a] Bacon's Novum Organon, lib. i. Aph. xxvii. and Opp. vol. ii. p. 8.

[b] Journal de Physique, vol. lxxi. La Metherie, Leçons de Geologie, vol. i. p. 224. Bailly.

It has been supposed [a] that islands were particularly numerous on the east of continents; unfrequent on the west; but the exceptions to this rule are too many to allow us to deduce from it any general conclusion. Great Britain, the Isle of Man, the Orkneys, Shetlands, Hebrides, the Scilly Islands, the Canaries, Madeiras, Azores, are all situate on the West.

To determine the Age of the world has long been a favourite object with philosophers. Halley, having persuaded himself that the sea increased in saltness, suggested, as a mode of solving this problem, an examination of the quantity of salt contained in a given portion of sea-water, in distant periods of time. Ricupero counted the beds of lava upon Etna, and, from the average of time which he supposed to intervene between the several eruptions, undertook to calculate the age of that mountain,

[a] Bacon's Novum Organon, lib. i. Aph. xxvii. and Op. vol. ii. p. 8.

and by analogy, the age of the earth. The disintegration of rocks, the mouldering of hills, and the gradual filling up of valleys, by the debris which falls into them, were adduced by Burnet, as conclusive arguments against the high antiquity ascribed to the earth by the writers of that day. Deluc, Dolomieu, and Cuvier have distinguished themselves by the attention they have bestowed on other instances of diurnal change. After a patient investigation of the phœnomena of bays, promontories, deltas, dunes, taluses, seas, lakes, and rivers, they are agreed in thinking that the period of time, which has elapsed since the retreat of the diluvian waters, cannot exceed from five to six thousand years.

So much for the positive age of our planet; — let us now consider its age in relation to different events connected with its own history, the history of the solar system, and the history of mankind.

That the order of things, as it existed

before the deluge, cannot have differed widely from the present order, will appear from many considerations.

1. The earth having acquired a spheroidal figure, while fluid, must have revolved even then upon its axis of fixed rotation; now it is extremely improbable that the earth should have had this motion at a time when the sun and planets were not yet called into existence.

2. In the diluvian detritus of almost every country which has been examined, have been discovered bones of the horse, ox, stag, elephant, and other quadrupeds. These animals inhabited the earth; consequently they had land to roam on, plants to feed on; the animals and plants grew and flourished: consequently they must have enjoyed an atmosphere and a climate suited to their nature; in other words, an atmosphere and a climate varying little from those of the present world. If so, may we *not* conclude that the antidiluvian earth was a planet belonging to the solar system, re-

volving in an orbit little different from its present orbit, and undergoing all those periodical changes, upon which climate, temperature, vegetation, and animal life depend?

3. The several planets are spheroidal like the earth; therefore they have been fluid: and they agree with the earth in so many other particulars, that physical astronomers do not hesitate in ascribing to both a common origin.

Dr. Herschel deduces from his observations on Nebulæ, that they consist of rare and luminous matter, gradually condensed in consequence of the attraction of denser nuclei which they surround; if we may suppose the heavenly bodies formed by the same process, Comets, he thinks, would afford an example of an imperfect, Planets of a complete condensation of such matter.

The author of the Mechanique Celeste, has with becoming caution advanced a similar hypothesis; he supposes that the matter of the solar atmosphere expanded by exces-

sive heat to the limits of the solar system, revolved formerly round the centre of gravity of the system, and that this matter becoming condensed by cooling, the greater portion of it was attracted to the sun, its centre; but smaller portions to as many other centres as there are planetary bodies: the zodaical light he attributes to the remaining portions of the same atmosphere still uncondensed and revolving round the sun.

By this hypothesis, La Place is enabled to account for the former fluidity, and present spheroidal figure of the planets, for the small eccentricity of their orbits; and for the motions of the sun, the planets, and their satellites upon their axis of rotation, and of the planets and their satellites in their orbits being in the same direction, and nearly in the same plane; for the bodies thus formed, will necessarily retain the motion of the atmosphere in the plane of its equator, and the exterior zones of atmosphere having a greater absolute velocity than the interior, the bodies formed by the condensation of such zones, will have a ro-

tatory motion in the direction of the motion of the atmosphere itself.

The extent of the operations which we have here contemplated, is so vast as to be embraced with difficulty by the most capacious mind.

Long accustomed to admire that uniformity of movement which the lapse of five thousand years has been unable to disturb, having continually more and more reason to believe that the solar system contains no seeds of decay, and that, as far as the motions of the sun and planets depend only on their mutual action, that system may have subsisted from, may endure to eternity, we are naturally slow to admit that the world has ever existed under circumstances so different from the present as these theories suppose: but experience cannot furnish a clue to the history of times extremely remote from those in which human experience has been collected; and the spheroidal form of the earth is, of itself, sufficient to convince us, that the course of

nature has not always been uniform, that her laws are not absolutely fixed, and that the solar system, unchangeable as it now appears, has, notwithstanding, had a beginning, and may have an end.

This opinion is further supported by analogy. Within the short period of astronomical observations, changes are known to have taken place in some of the heavenly bodies, changes no less extraordinary than those which La Place and Herschell imagine, at an earlier period, to have affected the earth. As an instance of this, we may mention a star in Cassiopœa: first observed in 1572, it gradually acquired a brilliancy which exceeded that of Sirius, so that it could be seen during the day; but this brilliancy soon declined, and in 1574 the star was no longer visible; and yet, in all probability, it continues to exist in the region where it was last observed, though in a state of opacity; for its change of splendour was not attended with any change of place.

"How prodigious a change" exclaims

La Place, "must this vast body have un-
"dergone! how far do such operations
"surpass any which our sun presents!
"how clearly do they prove to us that
"nature is far from remaining always and
"every-where the same!"

Whatever weight the reader may be disposed to give to the hypothesis above quoted, I think he will be disposed to admit all I wish him to admit at present, *viz.*: That the several planets acquired their positions, their spheroidal forms, their fixed axes of rotation, their velocities and the common direction with which they move upon their axes and in their orbits round the sun, at the same time and by the operation of the same cause; and consequently that the diluvian catastrophe did not take place till after the establishment of the solar system.

That the earth was divided into land and water, at a period antecedent to the deluge,

is evident, from the remains of land and sea productions so abundantly diffused throughout the secondary rocks ; but the situation which the land and sea respectively occupied before this event, appears in many instances to have differed materially from that which has been since assigned to them. This circumstance, which we might have reasonably anticipated, on considering the changes of form which the surface of the earth must necessarily have undergone, from the excavation of rock in some places, and the accumulation of detritus in others, appears indisputable when we contemplate the situation of the different places to which bowlder stones and gravel have been transported.

The blocks of granite on the Jura attest the non-existence of the Lake of Geneva, at the time of their transportation.

The similarity of the parasitic gravel and soil at Malta and Gozo attests the non-existence of the Mediterranean at the time the gravel and soil arrived at these islands.

The blocks of primitive Norwegian rocks scattered over the North of Germany, Russia, Holland, and occasionally met with on the eastern coast of England, attest the non-existence of the Baltic and German Sea, while these blocks were in motion.

Pieces of granite are found on Staffa, which could only have been brought thither when Staffa was annexed to the main-land; and similar phenomena will probably be found in every other part of the world, when they become objects of inquiry.

The newest formations with which we are acquainted are intersected by valleys, and covered by alluvial deposits: hence it follows that this event was posterior to the birth of these formations.

Inattention to this circumstance has occasioned many errors in Geology. I remember being told by a Professor on the Continent, that the frequent change of texture, colour, and grain, observable in the granitic

rocks in the neighbourhood of Heidelberg, was owing, he conceived, to the depositions having been disturbed by the great valleys of the Rhine and the Neckar. Though Lamanon thought that currents were rather the effect of valleys than the cause of them, even He, has not always distinguished the process by which strata were formed from that by which they were mutilated; and Dolomieu[a] furnishes, in one of his best memoirs, an example of that unfortunate association of order and confusion, which, for want of correct notions on the subject, he has ventured to ascribe to nature.

If this event was posterior to the consolidation of the most recent rocks, it was obviously posterior also to the interment of the fossil organic bodies which these rocks contain.

Woodward, Scheuchzer, Buttner, Lehman, and the pupils of Hutchinson, attributed fossil shells to the deluge, as the

[a] Journal de Physique, vol. xxxix. p. 391.

common people generally do at this day. Stukely[a] also fell into this very natural error. "If," says he, "we observe, how "the Lincolnshire Alps run fifty miles "north and south, and on the west are "steep and rocky, we see why the strata "near Newark are so stocked with shells; "for it is reasonable to suppose, that on "the retiring of the waters of the deluge "from the superficies of this country into "the eastern seas, these heavy bodies "were intercepted by this cliff, which has "retained such vast quantities of them ever "since, while those that fell on common "mould are mostly rotten and now lost."

Targioni[b], Arduino, Rouelle[c], Hollman[d],

[a] Transactions of the Royal Society for 1719.

[b] Targioni and Arduino maintained that there had been many deluges. See Breislack's Introduction to Geology, p. 376.

[c] Rouelle shewed that fossil shells do not lie at random; that different kinds of shells are found in different places; and that they occur in different strata.

[d] In an elaborate treatise published in 1772, in the Introduction to the Journal de Physique, tom. ii.

Gesner, Buffon, Whitehurst[a], &c. have succeeded in some measure in correcting this error: but many of our cotemporaries are, I fear, in danger of falling, some of them, indeed, have actually fallen, into a mistake no less grievous; that of attributing the productions of the Sub-Appennines[b] to the Adriatic, and those of Nice[c] to the united waters of the Euxine and Caspian forcing a way through the Hellespont into the Mediterranean.

I am at a loss to determine by whom it was first observed, that fossil shells had their nearest analogies in climates different from those in which they are now found.

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p. 118, Hollman contends that fossils are not owing to the deluge, a doctrine advanced shortly afterwards by Gesner (Journal de Physique, Introduction, tom. ii. p. 608. but with some modifications.)

[a] Whitehurst (Theory of the Earth, p. 59.) says, that beds of fossil shells which consist of one species only, and are not native to the climate where found, but of very distant regions of the earth, show that the inhabitants of these shells have lived and died in the beds in which they are found.

[b] Brocchi Conchyologia Sub-Appennina.

[c] Rizzo. Journal de Physique.

The circumstance was well known to le Maillet[a], Jones[b], and Catcott.[c]

In the petrifactions of Monte Bolca, where the impressions of fish are preserved between the laminæ of a calcareous schistus, a hundred and five different species have been enumerated; of which thirty-nine are said to have come from the Asiatic seas, three from the African, eighteen from those of South, and eleven from those of North America. It is a saying which, I presume, the observations of M. Cuvier will not warrant; but admitting the fact, are we to believe that Monte Bolca has been situate in different and distant places at one and the same time? that all these various animals repaired to this spot, (the area of which does not exceed that of the Banqueting-house at Whitehall,) from seas occupying the opposite quarters of the globe? seas, which, as has been shewn, did not exist till after their supposed inhabitants had emigrated and pe-

[a] Telliamed.
[b] Physiological Disquisitions.
[c] On the Deluge, p. 251.

rished? or is it not more reasonable to suppose, in compliance with the theory here advanced, that there is no connexion between these recent bodies and the fossil ones, except that of resemblance?

Jussieu [a] pronounced the plants of which impressions are met with in the coal mines of France, to be tropical. The resemblance is admitted; but here again I ask, shall we believe that France once possessed the loco-motivity piously ascribed to the Chapel at Loretto? or that these plants, growing on a soil not yet in existence, floated with impunity over the not yet existing Atlantic? or, rejecting both these suppositions as contrary to common sense, shall we not believe, that the resemblance between the impressions of plants found in the Coal Mines of France

[a] Even Mr. Playfair conceives that these proofs of the transportation of materials "*by the sea*," have the advantage of involving nothing hypothetical, and that the accurate comparison of the animal exuviæ of the mineral kingdom with their living archetypes, may lead to important consequences concerning the nature and direction of the forces which have changed, and "*are continually* changing" the surface of the earth. See Illustrations, p. 178.

and those now growing between the tropics, is merely accidental? that they are productions of a similar climate if you please, but not of the same world?

Alarmed by the conclusions which necessarily flow from such premises, as that our northern strata owe their fossil productions to southern climates, many naturalists have of late attempted to prove, that the fossils in question, though reputed tropical, do in fact exist in seas nearer home; but, though they should succeed in this attempt, which I doubt, the chief difficulty will still remain; for let it be assumed that the archetypes of shells found in France, are those of the Atlantic; in Italy, those of the Adriatic and Mediterranean; still we might as well suppose, that Hannibal obtained his vinegar from a modern commissariat, as suppose, that the fossil shells of France and Italy were derived from the seas in their vicinity, before those seas were in existence.

That the Deluge in question was posterior to the birth of mineral veins, and many, if not all, basaltic dykes, is deducible from the

intersection of these veins and dykes by valleys, and the occurrence of their detritus in stream works.

Werner[a] tells us that the occurrence of veins depends much on the external form of mountains.

1. On the position of the whole chain of mountains in respect to its extent and declivity.

2. On the particular position of the country where they occur.

Whether the country be composed of hills with gentle declivities and roundish or flattish summits, or

Whether it be a place in a principal valley.

Those who can unravel the meaning of this passage will find the ideas contained in it erroneous.

He supposes also, that the fissures in which metallic ores occur are often occasioned by mountains having fallen to-

[a] Werner on Veins, Translation, p. 54.

wards the sea or valley; if so, we have shown, that such sea or valley must have existed before any which now exist.

We have no positive evidence to determine whether the deluge took place before or after the Creation of Man: we have only this negative evidence, that neither any part of a human skeleton nor any implements of art have been hitherto discovered, either in regular strata, or in diluvian attritus.

As for human bones, M. Cuvier[a] says, "it is certain that none have been met with "among fossils properly so called. Our "workmen about Paris almost all believe "the bones so frequently found in the gyp-"sum quarries to be human; but having seen "several thousands of these bones, I may "be permitted to say, that not one of them "has ever belonged to our species. At Pa-"via I examined a number of bones which "had been brought from the island of Ce-"rigo by Spalanzani, and, in spight of

[a] Recherches, Disc. Prelim.

" what that celebrated observer has said of
" them, I pronounce that not one among
" them is human.

" The fossil which Scheuchzer called
" *homo diluvii testis*, I have restored to its
" proper place among the Salamanders.

" At Canstadt in Franconia, a fragment
" of a human jaw was found, but we know
" not at what depth, or under what cir-
" cumstances.

" Every where else, the bones supposed
" to be human turn out to be those of some
" other animal."

Since this passage was written, human skeletons, imbedded in stone, have been found in Guadaloupe. Mr. Konig[a] has published an account of the most perfect, I believe the only one, of these that has been brought to Europe; in all probability the stone is a recent concretion of calcareous sand on the sea shore.

At the convent of Rossweil, in Swisserland, I was shewn a great curiosity, preserved in a shagreen case, richly carved and gilt on the outside, and lined with

[a] Philosophical Transactions, 1814.

velvet. The monks called by the name of an antedeluvian knife, a piece of limestone accidentally broken into a form somewhat resembling that instrument. Dr. Hook[a] gives several instances of ships having been found in mines and in the bowels of the earth.

It is said by Mr. Knight Spencer[b], that an ancient brass pin has been found in the heart of a flint; and an instance is adduced in the Journal de Physique[c], of copper nails having been discovered in limestone.

In the Journal des Mines[d], money is reported to have been seen in flint. Lamanon[e] mentions a key found in the interior of a block of gypsum at Montmartre, and La Metherie

[a] Posthum. Works, p. 439. 441. 443. See Whitehurst, p. 133.

[b] Bakewell's Introduction to Geology, p. 338.

[c] Tom. xxxi. Supp. p. 70.

[d] Tom. iv. p. 76.

[e] Journal de Physique, tom. xvi. See also on this subject, Linnæus, Wormius, Grew, Zannechelli, Henckel, Scheuchzer. Journal de Physique, for 1772. Introd. vol. ii. p. 549. Spalanzani, in Journal de Physique, vol. xlvii. p. 281. and vol. lxi. p. 51. vol. xxvii. p. 168. and vol. xiv. p. 302. Jacob's Travels in Spain. Guettard's New Memoirs, vol. ii. p. 314.

speaks of a horse-shoe, found under similar circumstances on that hill.

Joinville and de Saade, I think, have recorded an observation of the same kind which they made at Aix.

All these accounts are, however, too apocryphal to be admitted without further proof of their authenticity.

Of the bones which occur in diluvian gravel, some are analogous to those of species now existing; of others even the genera are unknown to us. What shall we say then? that man, the monarch of creation, was once the contemporary of the mammoth? or that the elephant, the horse, the pig, are of a more ancient family than an Howard and Montmorenci?

Thus have we been able to point out with some degree of confidence, the relative æra at which the deluge took place; but if we would proceed further, if we would investigate the means by which this tremendous catastrophe was produced, the mind is easily bewildered in unprofitable conjecture.

If the submersion of the highest mountains on the face of the globe was occasioned simply by an Increase of Water, from what source can so enormous an addition of water have proceeded? If it existed previously, what became of it during the growth of those land-plants, which we so often find imbedded in the secondary rocks? during the life-time of those land-animals whose fossil remains are so extensively distributed? if it existed at the time of the Deluge, what is become of it now? if derived from the interior of the Earth, as Sir H. Englefield supposes, (a supposition not easily reconcileable to what little we know of its interior from the experiments of Maskelyne and Cavendish,) how explain the existence of those enormous caverns, within which this mass of water was contained? how explain its own existence in such a situation? what attraction from without, what repulsion from within could have dislodged it from its hiding place, and forced it far beyond those barriers which the laws of gravity prescribe? how happened it that the roof and sides of the caverns, in which the water

resided, did not fall in during its absence, so as to prevent the possibility of its return? Was Increase of Temperature the means of dislodging it? whence did that increase of Temperature proceed? from within? we know not any cause acting from within capable of producing it; of producing it once, and once only, within a space of five thousand years: from without? how could heat be at the same time so intense as to penetrate a solid crust some thousand miles in thickness, and yet so gentle, that no traces of its action are discerned upon the surface, where it must have acted most intensely?

If it be supposed that this accession of water was derived from some body extrinsic to the earth, we know of no cause in nature by which such transfer of water from one body to another could be produced: but let a cause be assumed; let us grant that the water was so obtained; how was it afterwards removed? what is become of it now?

Shall we then, fearless of paradox, attribute to the waves constancy, mobility to the land? Shall we say that continents

have been submerged, not from the rising of waters, but from their own descent? Extravagant as such an hypothesis may appear, it falls short, very short of that which the Huttonians have long admitted and maintained. "There can be no doubt," says Mr. Playfair, "that the land has been "raised by expansive forces acting from be- "low; and there is reason to think that con- "tinents have alternately ascended and de- "scended within a period comparatively "of no great extent."

Under the sanction of such authority, may we not hazard the moderated theory, that, once, and once only, continents have stooped from their elevated station, in order to shield ourselves from the consequences, with which we are threatened by giving way to the swollen pride of the ocean?

Alas! this expedient, so far from obviating our difficulties, tends only to enhance them.

If there were no caverns beneath our continents, how could they sink?

If there were caverns, how were they produced? why were they commensurate with the extent of the land?

The continents having sunk, how have they risen again to their present level?

After all this subsidence and elevation, how happens it that of the strata which were deposited horizontally so many remain horizontal?

How happens it that subsidence and elevation were unattended by fracture?

But the submersion of the earth is not the only condition required to bring about a state of things such as we have described. Valleys could never have been excavated, nor huge bowlder-stones have been transported to so great a distance under water, had the water been subject to such comparatively trifling agitations only, as those by which that fluid is affected in the present constitution of the world.

To the solution of the problem Impetuosity of Motion in the water is indispensible; but an increased Quantity of water is, perhaps, superfluous; for there seems no good reason for supposing, that the quantity which actually subsists upon the earth, if thrown into a state of excessive agitation,

would not be of itself sufficient to produce all the phenomena of the deluge.

We have seen that previously to that catastrophe, the general state of things upon the earth was very much the same as at present; that there existed land and sea, both of them inhabited; that the earth was a planet revolving on the same axis as now, warmed by the same sun as now, and nearly to the same degree. We have seen also, that this order of things, so closely resembling the present order, was suddenly interrupted by a general flood, which swept the quadrupeds from the continents, tore up the solid strata, and reduced the surface to a state of ruin: but this disorder was of short duration; the mutilated earth did not cease to be a planet; animals and plants, similar to those which had perished, once more adorned its surface, and nature again submitted to that regular system of laws, which has continued uninterruptedly to the present day.

Where then was the cause of this transitory but tremendous disturbance?

We are not aware of any force depending

on the internal Constitution of the Earth, that could now effect so great a revolution as the deluge; therefore, it is not probable that the deluge was effected by a force residing *within* it, immediately before the deluge; for the constitution of the earth was at that period nearly the same as it is now.

Did the disturbing cause reside then in the mechanism of the Solar System? No; our knowledge of the laws which regulate the motions of the planetary bodies, aided by an experience of five thousand years, will not allow us to admit that this system contains any seeds either of derangement or decay.

It must have resided, therefore, *without* that system.

If we enquire the *extent* of the disturbance, it modified the outward form of the earth, but without affecting its interior constitution, or exerting beyond the confines of the earth any influence with which we are acquainted. The order of things, which subsisted immediately after the deluge, so much resembled the order of things which

subsisted immediately before it, as to preclude the supposition that the earth, when considered in the character of a planet, underwent during that eventful crisis any material revolution; such a revolution it must have experienced, if the force acting upon it had been either the cause or the effect of a change of motion or position in any other member of the solar system.

If then we would discover the Cause of this catastrophe, we must look for a Cause foreign to our globe, foreign to the solar system, capable of inundating continents, and giving to the waters of the deep unexampled impetuosity, but without altering the interior constitution of the earth, or deranging the sister planets; moreover the Cause must be transitory, and one which, having acted its part once, may not have had occasion to repeat it in the long period of five thousand years. Any supposeable Cause that would not fulfil these conditions, is insufficient for our purpose.

Would a Comet fulfil them? Much

would depend on its bulk and distance. It would not fulfil them if we suppose a Comet, large in comparison of the earth, to move in a line joining the centres of the two bodies, so as to produce a direct shock; but, if we suppose one of suitable dimensions to move in such a direction as would allow it only to graze the earth, it is not impossible that the shock of this body, a body, such as we require, out of the solar system, might produce the degree and kind of derangement which we are attempting to account for; I mean a great temporary derangement on the surface of the earth, unaccompanied by any material change of its planetary motion. Euler, who, in a treatise entitled "*De periculo a nimiâ cometæ "appropinquatione metuendo,*" has investigated the changes that would be made in the elements of the earth's orbit by a Comet, its equal in bulk, coming almost in contact with it, finds that the attraction of such a Comet would indeed alter the length of our year, but only by the addition of seven hours. The maximum effect resulting from the Comet's attraction at the time

of its passage, would be greater than we should be led to infer from the total result of its attraction, after its final departure; for the changes occasioned during its approach, would be in a great measure undone during its retreat; but even at their maximum they would not be very great, because from the rapidity of the Comet's motion, time would be wanting to complete them. A Comet grazing the earth, would be incompetent, Euler says, to produce even a deluge of our continents, unless the shortness of its stay were compensated by a magnitude of volume, exceeding that upon which he has founded his calculation.

I shall conclude by remarking, that if the hypothesis of a shock derived from the passage either of a Comet or of one of those numerous, important, and long neglected bodies, often of great magnitude and velocity, which occasion meteors, and shower down stones upon the earth, would explain the phenomena of the deluge, (a point upon which I forbear to give any opinion,) we need not be deterred from embracing that hypothesis under an apprehension that

there is in it anything extravagant or absurd. In the limited period of a few centuries, there is little probability of the interference of two bodies so small in comparison with the immensity of space; but the number of these bodies is extremely great, and it is therefore by no means improbable, says La Place, that such interference should take place in a vast number of years.

ESSAY III.

ON THE INEQUALITIES WHICH EXISTED ON THE SURFACE OF THE EARTH PREVIOUSLY TO DILUVIAN ACTION, AND ON THE CAUSES OF THESE INEQUALITIES.

I HAVE endeavoured in the preceding Essay to refer to their immediate causes, the inequalities which diversify the present surface of the earth; but, as the operation of those causes must have been greatly modified by the form of the surface on which they acted, it is necessary, in order to complete our enquiry, that we should endeavour to ascertain the figure of the earth in preceding ages.

While its construction was yet going on, is it probable that the surface of our planet exhibited one uninterrupted plane, or that

it was diversified then, as it is now, by protuberances and depressions?

In favor of the former opinion, may be cited the authority of Stracey, Hutchinson, and many of the early writers. Believing that the materials which constitute the solid crust of the globe, were deposited from a fluid menstruum, in obedience to the laws of gravity uninfluenced by disturbing causes, they inferred, *à priori*, that every stratum must have been originally plane or rather concentric. The observations of Dr. Richardson [a] go to justify that inference: for though the upper surface of superficial strata is continually scolloped away, the plane forming their base, he says, continues always steady and rectilinear, and the upper and under surfaces of those beneath he finds invariably parallel to one another.

These observations, however, I apprehend, are just only when applied to districts of inconsiderable extent. Even along

[a] Philosophical Transactions for 1808.

the coast of Antrim, it would not be easy to find the surface of the chalk unlacerated for a mile together, protected as it is by its thick cover of whinstone.

The Blackheath gravel bed is made up of chalk flints; the chalk must therefore have been partially destroyed before this bed was formed.

Can the chalk of England be unlacerated where covered by a stratum of Woolwich pebbles, pebbles which consist of rounded flints broken from the chalk beds?

Mountain chains, composed of primitive rocks, are often separated by valleys in which the rocks are secondary. Between the Ocrynian ridge in Cornwall and Devonshire, and the mountains of Wales, red sandstone, mountain limestone, coal-measures, &c. unconformably disposed, occupy a valley, through which has since been excavated, by diluvian action, the interior vale of the Severn; similar intervals between the Welsh and Cumbrian mountains, between these and the Cheviots, between the Cheviots and the mountains of Scotland,

exhibit similar appearances. How could these hollows and ridges be so occupied, if protected strata were always even, or if the surface of the primitive strata had not been uneven in these places at the time when the secondary strata were deposited? Granite, commonly said to be the basis on which all other rocks repose, is found on the highest eminences, at the lowest depths with which we are acquainted. Coal is often represented as occurring in basins or troughs. Who has not heard of the upfilling of strata? these are additional instances of irregularity of surface in protected strata.

Many of the secondary rocks contain pieces of wood or impressions of fern or fossil shells. Unless we suppose that marine moluscæ inhabited the land, or timber grew upon the ocean, we must admit that there existed, at the time when these were deposited, land and water; in other words, mountain and valley.

Inequalities of surface prevailed then,

even during the formation of strata; to what causes are these inequalities to be referred?

1. Crystallization.

This term is employed in different senses. It sometimes means an aggregation of integrant molecules arranged by polarity into a definite essential form, each molecule being composed of the same elements united in the same proportions. Professor Jameson appears to think that even this, the most perfect species of crystallization, has not been inactive in determining the figure of the surface of the earth: what are called strata he supposes to be in many cases mere laminæ of crystals, which, being produced, would be found to meet at determinate angles. I do not know the grounds on which this opinion rests; but strata and beds agree so closely in character, that I cannot persuade myself they owe their existence to different causes. Now there is no instance known of a crystal made up of dissimilar laminæ. The primitive molecule of many

of the metals is the same, notwithstanding which we have never seen a crystal composed of layers of different metals; for instance, of red copper ore, galena, and iron pyrites; still less a crystal composed of alternate layers of substances, the primitive molecules of which are dissimilar, as alum and sulphur; how then can it be imagined that mountains composed of different strata, formed at different periods, are crystals?

By irregular crystallization, I understand a concurrence of similar or even dissimilar integrant molecules associated without regard to polarity. This prevails in all rocks which are foliated, radiated, or fibrous, and in many consisting of angular grains. The ingredients of these rocks, on being disengaged from the fluid which held them in solution, are thought by Rouelle, and his pupil Lametherie *, to have disposed themselves in obedience to the laws of elective attraction, in groups insulated at their sum-

* Journal de Physique, vol. xlii. p. 132. 294. and 445.

mits, united at their base. These groups it is said, formed original mountains, the intervals between them original valleys.

Their theory to this extent appears reasonable; but they have not stopped here: they have referred to irregular crystallization effects produced upon non-crystalline materials; upon brecchias, shell-limestones, &c.; even the cliffs near Calais, according to Lametherie, are results of crystallization.

2. Partial deposition.

This would result from the different state of the menstruum in different places, occasioned principally by tides and currents, the influence of which must have been felt from the first moment that the earth and moon were in existence; for the quantity of matter deposited at each place would be inversely as the quantity of motion in the fluid from which it was disengaged.

The multifarious productions of secondary rocks afford ample testimony of these

tides and currents. To what other cause can we attribute the frequent intermixture of animals inhabiting the land, with those inhabiting the sea? of wood, fern, bones of lacertæ, moluscæ dwelling only in shallows, with pentacrini dwelling only in the deeps?

If partial deposition tended, in some places, to increase subsisting inequalities of surface, in others it would tend to diminish them: it would tend to diminish them wherever the depositing fluid experienced interruption from ridges previously existing; that is, practically speaking, in all those situations where we find on one side of a mountain chain a different series of rocks from that which we find upon the other.

Thus porphyry is very common on the Italian side of the Alps, rising between Bolzano and Brixen to the height of 4000 feet, but on the German side it is altoge-

* See Journal de Physique, tom. xlix. p. 212. See also Voyages de Saussure, § 981. and Nicholson's Journal, vol. iv. p. 264.

ther wanting, On the German side, serpentine and other magnesian rocks abound, which are rarely met with on the Italian.

In the same manner the deposition of red marl, which occurs below the fells of Alston Moor, and the Cumbrian group, in the valley of Carlisle, does not appear to have ever extended beyond them.

3. Subsidence.

On the same principle as new houses settle, new rocks would subside, and this, not only in consequence of their own weight, but in consequence of the weight of other strata heaped upon them.

The degree to which this cause has operated may be ascertained; for every subsidence implies a fault, and consequently where there is no fault we may safely conclude there has been no subsidence.

It does not follow, however, conversely, that where there is a fault, there must have been subsidence; for, if new strata were now to be deposited, the faults would be

as numerous as mountains and valleys, occasioned not by subsidence but inequality of surface.

The relative period at which subsidences have taken place, may often be determined by examination of the superior strata.

The nature of the substances by which chalk is covered at the Isle of Wight, precludes the idea that they could have been originally vertical; they are vertical now and parallel to the chalk; hence the subsidence of the chalk could not have taken place till after the deposition of the beds that cover it.

The unconformable position of the red marl in this country and in France, evinces that the coal and limestone had acquired their inclination before this marl was deposited. It is commonly said in England, that the coal is cut off by the red ground; it would be more correct to say the red ground is cut off by the coal.

The general constancy which prevails in the direction and dip of mountain chains, countenances the idea that many of these

chains, however modified by diluvian action, owe their origin to subsidence.

4. Volcanoes and Earthquakes.

It is probable that the effect produced upon the earth by these, was confined in the earliest ages as now, to forming occasional hills by the accumulation of ashes and scoria, or occasional valleys by the falling in of unsupported craters.

But the action of running water appears to have been in all ages the principal cause of inequality of surface.

In many places, at the Valorsine notoriously, conglomerate is found interstratified with beds, to which, but for this circumstance, no one would deny the appellation of primitive. Croagh Patrick, a mountain which ought to be attractive to Geologists as well as Pilgrims, is composed of quarz rock lying amid clay-slate, serpentine and mica-slate, which contains in some places large nodules of quarz.

Dr. MacCulloch has given, in the Geological Transactions, repeated instances of the

same kind, which, being sanctioned by his own experience and that of continental observers, have induced Mr. Jameson to admit Quarz rock, Sandstone, Greywacke, and Conglomerate, into his list of primitive formations. I know — chemical products sometimes bear so striking a resemblance to mechanical, that it is not easy to distinguish them; and it is improbable that the rocks just mentioned are made up only of abraded portions of others previously destroyed; but few will deny that they contain some abraded matter; and that abrasion can be accounted for only by the instrumentality of running water.

If the effects of running water are faintly traceable on the primitive rocks, they are very conspicuous in those of a later period. "A great catastrophe," says Dolomieu [a], "seems to have taken place after the birth "of the primitive rocks, and before that of "the derivative or parasitical (*couches de "transport*). Regularity of structure ceas- "ed; a fracture took place in consequence

[a] Journal de Physique, tom. xxxix. p. 390.

" of some vast shock; vast it must have
" been, to break through a compact shell
" 4000 fathoms in thickness. The strata,
" which precipitation had arranged hori-
" zontally, and crystallization consolidated,
" were thrown up; some, vertically to a
" height which, since that period, the water
" has never attained; others, obliquely in
" various directions: thus were formed the
" great eminences of our globe, from which
" were derived its present irregularities of
" surface."

Without assenting to every part of this doctrine, I cannot but consider the almost universal occurrence of conglomerate and greywacke on the confines of what are called primitive rocks, as one of the most important and striking facts yet established in Geology: it seems to prove, that, at the epoch at which these beds were formed, a deluge took place, similar in kind, though perhaps not equal in extent, to that which determined the present outline of the earth.

From that period till the work of creation was complete, the mechanical action of

running water appears to have been more gentle and partial, but unremitted. The secondary beds are obviously composed, for the most part, of the ruins of their predecessors; their surfaces are continually water worn, and the alternate recurrence or intermixture of various productions of the land and of the sea, of fresh water and salt water, so eloquently described by Cuvier and Brongniard, is by no means confined to the narrow district, to the small number of beds, which forms the subject of their Essay on the Mineralogical Geography of the neighbourhood of Paris, but pervades, indiscriminately, almost every country in which transition or secondary rocks are found, and almost every member of those formations.

ESSAY IV.

ON FORMATIONS.

By the term Formation is meant a series of similar or dissimilar rocks, supposed to have been formed in the same manner and at the same period.[a] The idea is therefore purely theoretical.

Two circumstances are thought to justify our assigning to different substances a common antiquity and origin; an intermixture of their ingredients, and alternate occurrence.

[a] In Journal des Mines, tom. xxvi. p. 170, we are told that strata of the same formation may be of different ages; but the definition here given conveys the sense in which the word formation is, I believe, most generally used.

An intermixture of ingredients however proves little more than contiguity. Rocks admitted to be of very different ages often exhibit it, while it is as often not discoverable in rocks thought to be of the same age.

Near Ravenstone, in Westmorland, the passage from mountain limestone into greywacke-slate is imperceptible: at a short distance from this spot the greywacke-slate, inclined at a high angle, is covered by conglomerate, and rounded pieces of slate are enveloped in the horizontal limestone above: shall we say of the same beds, in one part of their course, that they are members of the same formation, in another that they belong to different formations?

Who can distinguish the greywacke-slate from the red rab in the neighbourhood of Milford Haven, or in the south of Ireland? Who can say, in Herefordshire, where the old red ceases and the mountain limestone begins? What mineralogist can draw a line of demarcation between the red marl and toadstone at Heavitree? between the old and young red on the shores of the

Bristol Channel? between the young red and mulatto along the vale of Geneva? between mountain limestone and slate in many parts of Devonshire? between limestone and lias in the district that stretches from Auch to Cahors? between lias and mulatto at Argenton? between mountain limestone and chalk in the Italian Alps? But will any one affirm that the rocks so blending with each other in external character are of the same formation?

So in regard to alternate recurrence. — Alternating substances are not always coeval; nor do coeval substances always alternate.

The limestones, which near Plymouth alternate with slate, agree with those which in Cumberland alternate with coal. Are the slate and coal of the same formation?

Granite is of one formation; Gneiss of another: Do these never alternate, or graduate into each other?

ON UNIVERSAL AND PARTIAL FORMATIONS.

Similar substances are occasionally found under similar circumstances in distant parts of the world. On this slight basis has been raised the imposing superstructure of universal formations.

Sir Robert Atkins [a] assumed, that if a line were drawn from the mouth of the Severn to Newcastle, and continued round the globe, coal would be found near that line, and scarce any where out of it. Werner's theory was more comprehensive [b]; he conceived that the greater part of the primitive, transition, and flötz formations were

[a] Strange's Phil. Transactions.

[b] It would seem from the following passages, that Woodward had an indistinct perception of the same theory.

"I was abundantly assured that the circumstances "of these things in remote countries were much the "same with ours here — that the stone and other ter- "restrial matter in France, Flanders, Holland, Spain, "Italy, Germany, Denmark, Norway, and Sweden, "was distinguished into layers as it is in England, &c. "— I got intelligence that these things were the same "in Africa, Arabia, Persia, and other Asiatic provinces,

continued in the same manner round the globe, though not uninterruptedly.

To form a correct opinion on this subject, we must descend from generals to particulars.

If we consider the individual strata of which a formation is composed, so far from being able to trace these round the globe, it is generally impossible to do so to the extent of a few miles; for the regular order of succession, as it is called, is perpetually disturbed, either by the interposition of a new substance, or the discontinuance of an old one, or the substitution of one substance for another, or the splitting of one stratum into many.

Chert, flint, septaria, gypsum, ball-iron-stone, cornstone, afford examples of beds naturally interrupted on the small scale. Greenstone and killas generally form huge

" in America," &c. — Woodward's Essay towards a Natural History of the Earth. Lond. 1702.

" This confirms what you say of the regular disposi-
" tion of the earth into like strata or layers of matter
" commonly through vast tracts." — Holloway's Letter to Woodward in Phil. Tr. vol. xxxii. A. D. 1723.

insulated lumps in the midst of slate. Rock-salt occurs only in patches; the ochre beds of Shotover cannot be traced to any distance; nor the fullers earth of Rygate and Woburn; nor the Bath stone; nor the Hedington stone; nor any other with which we are acquainted.

The beds of coral rag, and calcareous grit, which form the southern bank of the Isis from Faringdon to Oxford, are lost a little to the north of that town, and do not shew themselves again on this side of Yorkshire.

At Ingleton; in the vale of Llangollen; at Ravenstone; at Plymouth, mountain limestone reposes immediately upon slate, to the exclusion of the old sandstone which appears on the south of Shrewsbury, at Sedberg, &c., and forms a considerable range of hills along the banks of the Wye and the Uske. This limestone is covered by coal measures in the northern counties; by lias in the neighbourhood of Frome; by the inferior oolite near Doulting; by the superior at Mells. At Chewton Mendip, oolite is wanting, and lias covered by forest marble. At Chard forest marble is

also wanting, and lias covered by chalk. Near Charmouth, the green sand or mulatto rests on lias; at Blackdown on marl containing gypsum; the Purbeck and Portland beds are absent between Oxford and Abingdon, and the iron sand rests on Kimmeridge clay; the Kimmeridge clay is absent at Cumnor and Faringdon, and the iron sand rests upon the oolite of Hedington.

Greywacke and greywacke-slate are not seen, where they might be expected, along the northern edge of the secondary country which crosses Scotland from the firth of Forth to the mouth of the Clyde. In the county of Tyrone, the intermediate strata vanish in succession till chalk is very nearly in contact with granite.

Near Dresden, the primitive rocks are immediately covered either by coal-measures or by the quader-sandstein, a rock probably contemporaneous with chalk. Not far from Angers, gneiss and hornblend-rock are capped by a calcareous brecchia, abounding in shells and corals, apparently of the same date as the crag of Norfolk and Suffolk. In Auvergne, the primitive rocks

are covered partly by coal, partly by a fresh water formation.

At Altenstein in Thuringia, bituminous marl slate, with impressions of fish, rests immediately on granite.

At Quebrada-sicca in South America, and in the Isle of Trinidad, Humboldt found mountain limestone lying on mica-slate: the former of these is almost every where deficient in France, and the latter in England.

It is a mistake, therefore, to suppose, that broken stratification is to be found only in porphyry, and the more recent varieties of trap; and it is not a little extraordinary that the mistake should have originated in that school, which invented the distinction (with what propriety will soon appear) between partial and universal, principal and subordinate formations.

In Derbyshire, the limestone is so thick that it has never been sunk through; in Yorkshire its thickness does not exceed twelve fathoms; further northward, it is still thinner; but a compensation is said to take place by the intervention of sand-

stone and other beds which are wanting in Derbyshire. The northern part of the Holywell and Oswestry ridge consists of simple limestone; the southern, of limestone alternating with sandstone.

At Dudley the principal coal is ten yards in thickness; at a little distance they find, in lieu of it, three or four thinner seams of coal, with beds of sandstone interposed.

Enough has been said to make it evident, that neither any single stratum, nor single rock, nor any imaginable series of rocks can be traced in a continuous line round the globe. Similar strata, similar rocks, similar series of rocks are, however, found in different countries and in different hemispheres.

But will this similarity of character entitle us to suppose that they were once connected? products of the same æra? precipitates or deposits from the same solvent? Certainly not; for similar rocks are continually seen in very different formations. How often do we observe, in a mountainous district, recurring strata composed of the same substance, separated by a vast thickness of

strata composed of other substances! Is it not ascertained that the limestone of Melmerby Scar is more ancient than that of Alston? that the red sandstone of Cheshire is less ancient than that on the banks of the Uske? that the green sand of Blackdown lies lower in the series than that of Feversham? the oolite of Bath than that of the Isle of Portland? In mineralogical character these rocks agree with each other; and yet a mere agreement of mineralogical character has been thought sufficient to establish the identity of rocks situate at the opposite extremities of the globe!

The Shells which occur within the Basin of Paris, are said to occur also in Carolina and Virginia; be it so; are we to infer that the same Shell-bank once extended uninterruptedly across the Atlantic?

It is probable that rocks deposited in places at no great distance from each other, at the same time, were not always of the same kind. There seems no reason, for instance, why the granite of Cornwall should be contemporaneous with the granite of the Pyrenees, rather than with the slate. In cases

where two rocks, commonly supposed to be long to very different æras, are brought together, the series being incomplete, the insensible gradation, which these rocks display, clearly evinces that there has been no pause, no interval of time between their respective births. A little north of Rother Bridge, in Westmoreland, as has already been observed, there is an intermixture of character in the slate and limestone; although in the immediate neighbourhood these rocks are separated by the old red sandstone, and at Ingleton, not very distant, they lie conformably to each other, and rounded pebbles of the lower beds are enveloped in the upper. It would seem, therefore, that the mountain limestone at Ingleton was deposited at the same period as the old red, and not at the same period as the mountain limestone near Rother Bridge; in other words, that two beds agreeing in external character, containing the same fossils, and found in the same neighbourhood, do not belong to the same formation; while two beds having no such similarity in character or in their fossil contents, do. At Argenton, in

France, lias passes in like manner into green sand or mulatto, and even partakes of its fossils. Either this green sand then must be coeval with our inferior oolite, or the lias not coeval with our lias. If we assume that the beds of mountain limestone in Derbyshire are the same as in Cumberland, the toadstones of the one county must have been deposited at the same period as the hazels and plates of the other.

Unable to connect similar rocks of distant countries, obliged to connect dissimilar ones in the same neighbourhood, can any one uphold the doctrine of Universal Formations? Let him, who answers in the affirmative, reflect on the consequences which that doctrine involves. He must admit that, when the particles of quarz, feldspar, and mica, which had heretofore arranged themselves so as to form granite, changed their mode of arrangement so as to form gneiss, that change was conveyed with the rapidity of an electric shock from one end of the world to the other; — that the currents

of different hemispheres had so equable a motion; that the particles borne along by these currents were so equally assorted, that, within the tropics, and without, the same depositions began and ceased at the same moment; — that similar pebbles were detached from their native rocks, at the poles and at the equator, by equal forces acting under the same circumstances, and were deposited and cemented by the same means, and at the same time. All this he must admit, or reject *in toto* the doctrine of Universal Formations.

It has been supposed, that the [a] analogy observed in the rocks of different parts of the world does not extend to the secondary; but this opinion is erroneous. Coal occurs in China and the East Indies; the Gypsum of America agrees with that of Europe; the Portland bed has been recognized in the neighbourhood of Moscow; the Chalk and Mulatto of Cracow correspond to the Irish, and the Marlstone, which contains

[a] Cuvier Disc. Prelim.

ammonites in Hindostan is undistinguishable from that of Lyme Regis, or Whitby.

In the scanty[a] catalogue of rocks with which the Wernerians have furnished us, we find some, as granite, which are common to all climates; some, as primitive gypsum and serpentine, which are confined to a few spots; some, as topaz rock and whitestone, which are peculiar, or nearly so, to the neighbourhood of Freyberg. Yet we are told that the primitive, transition, and flötz rocks are almost all Universal Formations.

I am not aware that any enumeration has been published of the Formations which by Werner were considered partial. The only one adverted to by Mr. Jameson[b] is that of Wehrau, in Lusatia, which consists of sandstone, limestone, bituminous shale and iron clay, resting on loose sand. I have seen specimens of these in the collections

[a] So scanty that it does not contain even the fresh water beds of Saxony.

[b] Jameson's Geology, p. 63.

at Freyberg and elsewhere. Similar substances with similar fossils are found in this country; but, whether in the same relative position as at Wehrau, remains to be ascertained.

"Porphyry, Sienite, and Basalt, (says Mr. "Bakewell[a],) are evidently Partial Forma- "tions, and have been produced by local "causes, whose operations have been con- "fined to particular districts; no fact in "Geology appears more decidedly esta- "blished than this."

I shall probably have occasion to show in the course of these Essays, that, so far from being partial, the rocks, just cited, are among those which are most extensively diffused.

All the valuable coal-beds in Europe have been found associated with a particular series of rocks; but there are many other series, which contain coal of inferior quality, and in smaller proportion. In the one

[a] Bakewell's Geology, p. 119.

series the coal may be said to be principal, in the others accessory or subordinate. The unfortunate substitution of the term Independant for Principal has tended to bring into disrepute a division which of itself is useful. It may be right, however, to mention, that the words Principal and Subordinate must be here understood to refer only to the proportionate quantity and quality of coal in different formations, and not to the proportion of the coal as compared with other beds of the same formation. Even the ten-yard coal of Dudley, the thickest known, is very insignificant in comparison with the beds of sandstone and plate, with which it is associated.

The terms Principal and Subordinate, employed in the latter sense, may be useful when applied to small districts, but, applied to large, are at least premature. Minerals, which are extremely scarce in one country, are in another extremely abundant. Gneiss and mica-slate may properly be called subordinate in England, not

so in Saxony. Primitive limestone may be called subordinate in Sweden, not so in Greece. Gypsum may be called subordinate in this country, not so in the South of Europe. Mountain limestone, the principal formation in Derbyshire, is in Herefordshire only a subordinate formation.

ESSAY V.

ON THE ORDER OF SUCCESSION IN ROCKS.

We have seen that Formations are not universal, and that rocks found in different parts of the world, though similar, may be of different æras. We now proceed to a question not less important in a speculative, and far more important in a practical view. Let it be supposed, that certain rocks are known to occur in a certain district; will analogy enable us to predict the order of their occurrence? Do the rocks, of different countries, which resemble each other in external character, resemble each other also in relative position? or may a substance, which is superior to an adja-

cent substance at one place, be inferior to it at another?

The question is not difficult. Every one admits that rocks alternate; if so, they do not follow one another in regular order.

But. though every rock alternates with some others, it does not alternate with all. Flint alternates with chalk, clay with oolite, red marl with gypsum; but no one, I presume, has seen granite alternating with salt, or serpentine with lias.

On the other hand, there is often such an affinity between two substances, that, on meeting with the one, we may speculate with a high degree of probability on the near occurrence of the other; in this manner chert is associated with limestone; rock-salt with gypsum; coal with plate and gritstone.

Here, therefore, as in every other part of nature, we find uniformity and variety blended together; the succession of strata is inconstant, but there is a limit to the inconstancy.

Lehman appears to have been the first

who attempted a chronological arrangement of rocks; he divided them into two great classes — the Primitive and the Secondary.

To these, Werner added a third class, as partaking of the characters of both:[a] Was this an improvement? No: unless it would be an improvement to increase the list of primitive colours by the addition of mixed tints, or the list of notes in music by telling in the flats and the sharps. The object of classification is not to enfeeble distinctions, but to strengthen them. Hard lines are indispensable in science, the business of which is not to imitate nature, but make it understood.

The names which Werner assigned to his classes, are Primitive, Transition, and Flötz, or, to do ampler justice to the author's ideas by a more correct translation of his terms, Original[a], Intermediate, and Level.

The rocks of the first class, though all Original, are not all contemporaneous.

[a] Werner's Phraseology is unfortunate. Can there be a medium between primogeniture and horizontality?

Granite is older than gneiss, gneiss than mica-slate, mica-slate than clay-slate, clay-slate than primitive trap. Of [a] Original limestone there are several formations. A deluge is said to have taken place between the birth of these rocks, and that of the superincumbent sienite and porphyry; yet the porphyry, sienite, limestone, trap, clay-slate, mica-slate, gneiss and granite, are all equally Original.

Upon these rest the Transition rocks, and upon them the Flötz, to each of which is assigned a definite place.

Virgil's peasant fondly imagined his native village a miniature of imperial Rome. With a corresponding love of generalization, Werner imagined Saxony and Bohemia a miniature of the world. He set down, more or less correctly, the order in which different rocks had arranged themselves in the districts with which he was acquainted, and concluded, that such must be the order of their arrangement in every other district. His theory was useful as a standard of reference, an incitement

[a] Jameson's Geognosy, p. 127.

to inquiry, a clue to observation; but, unfortunately for Werner, his pupils viewed it in a different light; it was represented by them not as an hypothesis to be tried, but as a system to be [a] followed; a system mature at its first conception, and perfect in all its parts and proportions. To merit of so high an order Werner was not entitled.

It was long supposed that the prop and stay of every other rock in every part of the world, must be Granite. The genius of Buffon led him to dispute this proposition. From the texture of granite he inferred that quarz must have existed previously,

[a] Heureusement pour les sciences la nature produit de tems en tems des grands hommes qui avec un courage égal au grand savoir, s'élèvent au dessus des idées de leur siecle, et tracent le chemin pour les tems à venir. C'est ainsi que du cahos des masses éparses et pour la plupart inconnues, Werner a su batir le grand édifice de la Géognosie au quel il a attaché son nom.

Journal des Mines, t. 26. p. 168.

C'est dont un travail pour les siècles à venir, un triomphe pour quiconque saura aggrandir cette masse de connoissances, et un monument de gloire pour Werner, qui durera tant qu'il y aura une roche qui puisse attester le grand mérite de cette homme illustre.

Journal des Mines, t. 26. p. 198.

and that the disintegration of the quarz supplied a principal part of the materials of which granite was afterwards composed. Hacquet's[a] doubts upon the subject were better founded, though indistinctly expressed. Link[b] observed, that Granite, though it generally lies beneath other rocks, may not do so every where, and may, perhaps, in some places, even lie above them. It assumes too many forms to be every where contemporaneous. Granite will sometimes resemble granite less than it resembles porphyry or gritstone. When we consider at how late a period quarz has been formed in metallic lodes, we must not insist very strenuously (he says) on the extreme antiquity of granite.

Dolomieu, observing that the granite of Auvergne is covered immediately by lava, enquires, Whence did this lava originate? It is not probable that it originated in the granite; and, if not in the granite, there

[a] Reise, vol. ii. p. 46. 76.

[b] Anleitung zur geol. Kenntniss der Mineralien.

must be another rock still lower than the granite.

Saussure[a] remarks, that, although it may be true, as a general position, that granite is older than gneiss, it is evident from their mutual transition, inter-stratification, and conformity of dip, that these two rocks are occasionally coeval.

The alternation of granite and gneiss has been since observed in various countries; at Naundorf[b] near Freyberg; at the Schneekoppe[c] in the Riesengebirge; at Karpenstein[d] in Bohemia; in the Alps; in South America.[e]

Fragments of gneiss are found in granite at the Brocken, the most consider-

[a] Voyages, tom. ii. p. 228.

[b] By Karsten, Übersetzung von Peyrouse, p. 20. note.

[c] Jameson in Nicholson's Journal, vol. ii. p. 228. Charpentier's Beitrag zur geognostischen Kenntniss des Riesengebirges, part iv. p. 54. 63. Meuder's min. Reise und Einleitung. — Gerhard's Abhandlung uber die Umwandelung einer Erd und Steinart in die andere, p. 109.

[d] Von Buch's geogn. Beobachtungen, vol. i. p. 23. and Landeck; see Anderson's Observations in his translation, p. 23 and 113.

[e] Humboldt's Geographie des Plantes, p. 123.

able of the Harz [a] mountains, and in the neighbourhood of Vienna.

Granite alternates with gneiss and mica slate on the south [b] of the Taberg; [c] with eurite, or white stone in the Saxon Erzgebirge.

It rests on mica-slate at Reichenstein [d], in the county of Glatz; at the foot of the Eulengebirge; along the entire ridge of the Riesengebirge; in Moravia and the Tyrol.

It alternates with mica-slate at Lugnaguilla in the county of Wicklow, and at Derryclare in Conemara.

That granite frequently alternates with Shist, is attested by Pallas [e], Soulavie [f], La Peyrouse [g], and Saussure. [h]

[a] Schubert's Geognosie, p. 110.
[b] Napione in Bergm. Journ. vol. ii. p. 2006.
[c] Raumer's geogn. Fragmente.
[d] Von Buch's Landeck translation, p. 44 and note. Geogn. Beob. vol. i. p. 37. Schubert's Geogn. p. 110.
[e] Helvet. Mag. 175. 2 Pallas Reise, 517. 520.
[f] Soulavie, vol. iii. p. 162.
[g] La Peyrouse sur les Mines de Fer. 325.
[h] Voyages, § 662 and § 676.

According to Jameson[a], the granite mountains in Arran rest on clay-slate.

A rock, differing from granite only in the imperfect cohesion of its ingredients, is found, in many parts of Cornwall and Devonshire, incumbent upon killas. Alternations of the two substances are seen at Huel Fortune near Marazion, and at the more celebrated mines of Cooks-kitchen and Dolcoath. At Gwarnock, in the parish of St. Allan, a steatitic granite accompanies the lode, which is worked in killas. The Morwelham tunnel, driven through a killas country, traverses three distinct beds of grauany elvan. At Cliggar point, on the east of St. Agnes, a rock of the same nature lies upon killas.

At a small cove, called La Poulet, in the neighbourhood of Cherbourg, I have observed killas passing into granite, and dipping beneath it. Of the intermixture of these substances numerous examples may be found in Cornwall; in Wicklow; in the

[a] Von Buch's Norway, Black's translation, p. 139, note.

Mourne mountains; at the Lowren-hill in Galloway; in the Grampians; in the Isle of Arran, &c.

Subordinate beds of hornblend-rock occur in granite, at Gwindu in Anglesea; and at Kilranelagh in the county of Wicklow.

Granite rests upon hornstone slate (hornschiefer) at Ehrenberg[a]; it alternates with it near Tschito[b] on the banks of the river Ingoda; and at the Chalet de la Para near Chamony[c]. At Kandy[d], a village in Tartary, it alternates with hornstone; at St. Michael's Mount in Cornwall with quarz; in the Pyrenees[e] it rests upon serpentine.

Granite reposes upon limestone in various parts of France[f], in Corsica[g], in the

[a] Voigt's min. und bergman. Abhandl. vol. i. p. 144.

[b] Patrin. Journal de Physique, vol. xxxviii. p. 229 and 289.

[c] Saussure's Voyages, § 676.

[d] Patrin. Journal de Physique, vol. xxxviii. p. 229, and p. 289.

[e] Peyrouse sur les Mines de Fer. p. 329.

[f] Bertrand Journal des Mines, vol. vii. p. 376.—He appeals to Faujas and Soulavie.

[g] Dolomieu Journal de Physique, vol. xxxix. p. 9.

Tyrol [a], and still more frequently in the Pyrenees.[b] Soulavie refers to an adit driven from one of these rocks into the other, so that there can be no mistake as to their relative position. A later writer tells us that in the ridge last mentioned, granite, porphyry, trap, corneenne, petrosilex alternate with limestone, and are so intermixed with it at the point of contact, that it is impossible not to consider all these substances contemporaneous. At one place a bed of granite, from 20 to 25 centimetres in thickness, is incased in a bed of trap, which is itself incased in limestone. The trap dwindles away till the included granite touches the limestone, which is then penetrated by zigzag veins and nodules of granite; these two rocks at their junction are firmly cemented together.

It is said that between Weisbaden and Idstein, M. Habel found a fossil shell in

[a] Ann. de Chym. vol. xiii. p. 166. Duhamel, Journ. des Mines, vol. viii. p. 751. and 756. See also Palassou's Description des Pyreneés.

[b] Collini, Considerations sur les Monts Volcaniques. Bergman's Manuel, vol. ii. p. 272.

granite: Is the specimen now in existence?

"I found in the neighbourhood of Chris-
" tiania, says M. von Buch[a], rocks evidently
" belonging to the transition series, which
" till now no one ever suspected to belong
" to it: immense mountains of porphyry
" resting upon a limestone, full of fossils;
" over this porphyry, sienite and granite,
" in composition agreeing entirely with
" that of the oldest formation. Granite
" above transition limestone! Granite a
" member of the transition series!"

Messrs. Brongniart[b] and Omalius d'Halloy consider the granites in the Cotentin more modern than the adjacent slate and limestone, in which are found organic remains.

On the eastern[c] side of the Erzgebirge, granite rests on greywacke and greywacke slate; it probably occupies the same position in Somersetshire, Caernarvonshire, and Worcestershire.

[a] Von Buch's Travels in Norway. — transl. p. 45.

[b] Journal des Mines, tom. xxxv. p. 126.

[c] Raumer's geogn. Fragmente, Bonnard in Journal des Mines, tom. 38. Ann. de Chemie, vol. i. p. 210.

"In the Saxon Erzgebirge[a], says Jame-
" son, we observe the oldest gneiss covered
" by clay-slate, which contains beds of flinty
" slate, greenstone, limestone, and por-
" phyry; over these rests, in a conformable
" position, newer granite, which alternates
" with sienite, gneiss, and porphyry."

Analogous observations have been made, in the Alps, by Ebel, Escher, and Saussure; in the Thuringian Forest, by Heim; in Scotland and its Islands, by Professor Jameson, and Dr. Mac Culloch.

I had occasion some time since to visit Les Trois Couronnes, situated on the north eastern frontier of Spain. This mountain is well known: Mina was encamped upon it during the late war, and it has been, in earlier periods, repeatedly the scene of important events, both military and political: from the boldness of its out-line, and its proximity to the sea, this mountain forms one of the most conspicuous objects on the eastern side of the Pyrenees.

Ascending from the ferry over the Bida-

[a] Von Buch's Travels in Norway, p. 283. *Note.*

soa; we first met with a rock of mountain limestone, and afterwards with a conglomerate, made up of pebbles and grains of very various sizes, all derived apparently from the debris of older rocks in the neighbourhood. It contains pieces of black slate, and alternates with thin beds of this substance. Higher up, the beds of sandstone or conglomerate become less frequent, till at last this rock entirely ceases, and the slate, which lately alternated with it, becomes the prevailing rock of the district. The different beds of this assume different appearances; some, which have the aspect of greywacke-slate, from the broken scales of mica, irregularly disseminated through their substance, are interposed among others, which, from their glossy and uniform surface, seem to have a claim no less decided to a place among the clay-slates; some might fairly rank with mica-slate; and the older members of this series alternate with granite, which, at first occurring in diminutive beds, gradually acquires importance, and at last constitutes the three summits, which give name to the mountain.

This granite, wherever I had an opportunity of examining it, exhibited the same characters; small grained, imperfectly crystalline, prone to decomposition, of a yellowish grey tint, it very much resembled the common grauan of Cornwall, to which it is also analogous in its metallic lodes, tin and copper having formerly been worked in it.* Its alternations with the slate or killas are numerous and distinct; in some places the beds of granite and slate do not exceed a yard in thickness; but they are evidently beds, not veins, for they lie parallel to each other.

The Wernerians acknowledge three formations of granite. The first is gratuitously supposed to be fundamental. I say gratuitously, for, by the terms of the proposition, the bottom of this formation has never been seen, and consequently we have no means of ascertaining whether it be fundamental or not.

* In addition to the substances already noticed, there are upon this mountain an elvan-greenstone and hœmatitic iron-stone.

The second consists of veins traversing the former. Are these veins, which evidently bear to granite the same relation as calcareous veins to limestone, entitled to the dignity of being called a formation?

"The third occurs sometimes in the "state of veins, sometimes of uncomform-"able beds:" if so, might it not be properly divided into at least two formations? and might not one of these be allowed to merge in that last mentioned?

These three formations appear to me useless. It is more simple to say, the relative position of granite is inconstant.

That equal uncertainty prevails in the relative position of the other rocks usually denominated primitive, will be rendered evident, I think, by the following sections.

Section from the Junction of the Isere and Ar, in Savoy, along the Valley of Maurienne, over Mont Cenis, to Avigliano.

On the North of Mont Cenis.

Mica-slate

Gneiss

Compact Feldspar
Siliceous Slate, or lamellar feldspar
Primitive Gypsum
Primitive Clay-slate
Mica-slate
Primitive limestone
Primitive clay-slate
Mica-slate
Primitive limestone and gypsum
Gneiss
Primitive limestone
Mica-slate
Primitive Gypsum

Section on the South Side of Mont Cenis.

Mica-slate Primitive limestone Serpentine Primitive clay-slate	Alternating all the way from the summit of Mont Cenis to Novalese.
Quartz	
Primitive limestone Serpentine Mica-slate	Alternating.
Veined Granite	

Serpentine and other varieties of magnesian rocks extending to Avigliano.

Section from St. Maurice, in Unterwald, through the Valley of Antremont, over the Great St. Bernard, through the Vale of Aosta to Yvrea.

On the North of the Great St. Bernard.

Gneiss
Lamellar feldspar
Compact feldspar
Coarse-grained Greywacke
Fine-grained Greywacke
Primitive Clay-slate
Coarse-grained Greywacke
Mica Slate
Gneiss
Lamellar feldspar
Primitive limestone
Mica-slate
Gneiss
Primitive Gypsum
Primitive Clay-slate
Primitive Limestone
Gneiss
Mica-slate
} Alternating.
Gneiss
Hornblend Slate
Primitive Clay-slate

White and black Quartz
Mica-slate with Garnets.

On the South of the Great St. Bernard.

Primitive Clay-slate with veins of Gypsum
Mica-slate
Gneiss
Quartz
Primitive Limestone
Gneiss
Primitive Limestone
Hornstone
Mica-slate
Potstone
Actinolite, with or without Garnets
Primitive Limestone
Gneiss
} Alternating.
Mica-slate
Primitive Limestone
Primitive Greenstone and Serpentine.

In Ebel's work, from which these sections have been taken, will be found several

other sections, tending to the same conclusion.

So much in regard to the Alps; proceed we now to the Pyrenees.

"The Pic du Midi de Bigorre[a] consists "entirely of primitive rocks in continuous "distinct beds, dipping between 60° and "80° from the general chain of the Py-"renees.

"The lower beds consist of limestone, "alternating several times with compact "feldspar (roche de corne) and perhaps "trap.

"The upper beds are micaceous gneiss, "and grenatite.

"Above the gneiss are a great many "alternate beds of limestone, trap, roche "de corne, and now and then of granite.

"The roches de corne often assume the "most fanciful curves, though lying be-"tween beds of limestone, whose strata "are plain.

"Granite occurs in the upper beds, as "a vein, as a bed, and as an ingredient in

[a] Duhamel, Journal des Mines, vol. viii.

" the limestones: in this last case it is
" found only on the surface, as if deposited
" immediately after the consolidation of
" the calcareous molecules."[a]

The following is the Order which the Primitive Rocks observe in the Saxon Erzgebirge.

Granite[b]
Gneiss
Mica-slate
Talc and Alum-slate
Clay-slate, with beds of Greywacke-slate, corneous Trap, Greenstone, and Lydianstone
Greywacke, with beds of Gneiss, Porphyry, Granite, Limestone, Slate, or Granite
Slate
Granite passing into Sienite, with subordinate beds of Gneiss, or of Porphyry and Limestone.

In various parts of Saxony you find

[a] Schubert, p. 104.
[b] Werner Kuzze Classification 14 — Charpentier 55. 57. 174. 201. 400.

Limestone lying under Gneiss, to the depth of 200 feet, or alternating with Mica-slate and Clay-slate.

At Klostergrab [a], in Bohemia, Gneiss rests upon Porphyry.

Beds of Hornblend, under different varieties, says Von Buch, appear to be subordinate to all the primitive formations.

If we consult Herman on the Urals, Von Buch and Hausman on the Norwegian Chain; Brongniart on the Cotentin; Raumer on the Harz; Heim on the Forest of Thuringia; Fichtel on the Carpathians; Dolomieu on the Vosges; we shall find, in each of these districts, anomalies no less remarkable than those which have been already detailed. In America, the order of succession, which the Wernerian theory prescribes to the primitive rocks, is so often varied and reversed, that Maclure [b] declares it impossible to arrange them in any regular series.

Groscke [c] states, that the Grampians pre-

[a] Voigt.

[b] Journal de Physique, vol. lxxii. p. 142.

[c] Bergbaukunde, vol. i. § 399.

sent alternate rocks of Gneiss, Clay-slate, Mica-slate, Clay-slate, Porphyry, and Granite; and the more detailed and accurate observations of Dr. MacCulloch and Professor Jameson have sufficiently established the uncertainty, which prevails, in the succession of the different primitive rocks, in the northern portion of our island.

According to the principle of arrangement adopted at the Geological Society, the several specimens ought to observe the same order in the cabinet, which they observe in nature; no attempt, however, has been made there, as yet, to arrange any of the primitive substances upon that principle; it is reasonable, therefore, to infer, that, in England, the order in which these substances occur, is either uncertain or unknown.

In Ireland, the order of succession of these substances is extremely variable; the Wicklow mountains are very differently constructed from those of Downshire, and the Downshire from those of Donegal, and Tyrone.

The primitive rocks ought to be followed by the transition, but almost every country, that has been well examined, presents numerous instances of transition rocks occurring in the midst of primitive districts, or primitive in the midst of transition. The writings of Brochant, Brongniart, Raumer, Von Buch, &c. abound in instances of this kind. The slate of Snowdon, and that of Tintagel contain organic remains.

It is commonly thought by foreign writers, that the secondary beds are more capricious, in the order of their occurrence, than the primitive and transition. A contrary opinion prevails in England. It is here supposed, that the secondary beds are extremely regular. Their irregularity however is very problematical.

The various Clays and Marls, which alternate with coal, lias, the different oolites, mulatto and chalk, are scarcely distinguishable from one another in their aspect or their properties.

Striated Gypsum is represented by the Freyberg school, as characteristic of a parti-

cular formation; yet, by some of the pupils of that school, it is placed beneath, by others, above the second flötz limestone. In England it is found associated not only with red marl, but with the Purbeck beds and the London clay.

Green sand or mulatto lies beneath the iron sand at Brill, and Apsley Guise; at Pusey, above the iron sand, but beneath the chalk; at Reading above the chalk, but beneath the London Clay; at Bagshot-heath above them all.

If Trap had a definite position in the series, it would not be found in the old sandstone of Herefordshire, in the mountain limestone of Derbyshire, in the coal measures of Staffordshire, in the lias of Perthshire, in the chalk of Kinbain.

At the Clee hills, and on the banks of the Avon near Bristol, the Mountain Limestone is oolitic; the Lias is oolitic in Glamorganshire; at Hambden Hill in Somersetshire, the Bastard Freestone is oolitic. The Bath stone is an oolite; the Heddington stone an oolite; the Portland stone an oolite; has the Oolite then any determinate place in the order of succession?

In Saxony and Silesia Coal is said, and I believe with reason, to lie beneath the old red rock; in the North of England it lies sometimes above the mountain limestone, sometimes beneath it. That, which is raised in the eastern moorlands of Yorkshire, is associated with rocks of a more recent epoch even than the lias. There is scarcely one of the secondary beds in which coal has not been observed, although perhaps of bad quality, and in beds of insufficient thickness to pay the expence of working them.

Even between the primary and secondary "formations" the line of demarcation is far less distinct than has generally been supposed. Green-stone and slate are found in every formation. I have a specimen from the West Indies, of a greenstone, which has every character of the primitive except that it contains shells. Hornstone porphyry occurs, as a flötz rock, in Arran; granular marble, in Dalmatia; serpentine, in Fifeshire; mica-slate, in the Valais; granite and sienite, in Saxony and Norway.[a] On

[a] Wild's Salines, p. 75.

the other hand, quartz-rock occurs as frequently in the coal formation, or in beds which cover the chalk of the basin of Paris, as it does in the primitive districts of Schichallion, Wicklow, and Conemara.

It is said in the Wernerian theory, that, after the formation of all other strata, an immense deluge suddenly occurred, and as suddenly retired, leaving, behind it, those scattered hummocks of flötz-trap, which have, for some years, so greatly engaged the attention of geologists.

The proofs of this catastrophe, we are informed, are to be found in the great elevation which these rocks occasionally attain; in their broken stratification; in their unconformable posture; and in the nature of their materials.

But are trap-rocks really more elevated than others? or their stratification more broken? It is time enough to consider inferences when we have established facts.

If the posture of trap is often unconformable, so is that of granite, sienite, horn-

blend rock, porphyry, primitive greenstone, &c.

Every rock without exception lies, sometimes, in a conformable, sometimes, in an unconformable posture: and perhaps the different members of the flötz-trap formation, as often exhibit a want of conformity towards each other, as, towards the beds on which they repose.

But the nature of its materials. — Many of them are precisely the same, as those found in other formations. The only rocks, which are cited as peculiar to, and characteristic of, the newest flötz-trap, are basalt, wacke, greystone, porphyry-slate, and trap-tuff. I am not sure, that I know what greystone is; the only locality, given of it by Jameson, is Vesuvius, where it is said to form a portion of the unchanged rocks. The doctrine that it belongs to the flötz-trap, therefore, is founded on an assumption, that we have the means of distinguishing, in volcanic countries, substances, which have been changed by the volcano, from those which have not: an assumption somewhat gratuitous. The remaining sub-

stances, viz. basalt, wacke, porphyry-slate, and trap-tuff, are certainly not peculiar to this formation, as in England, Scotland, and Ireland, they are, often, found interstratified with other formations much older. There is reason to suspect that, in Germany, trap-rocks, of very different æras, have been referred to the same æra, and that much of that which has been supposed the newest flötz-trap in Scotland, and which ought, therefore, to be more modern than the beds of the basin of Paris, is coeval with red sandstone, mountain-lime-stone, and coal.

ESSAY VI.

ON THE PROPERTIES OF ROCKS, AS CONNECTED WITH THEIR RESPECTIVE AGES.

I. ON THE INGREDIENTS OF ROCKS.

It was a favourite idea some time since, that the simple earths [a] were older than the compound.

It was supposed, also, that siliceous [b] rocks were older than calcareous. M. Lefebre [c] and M. Dolomieu took great pains in 1791, to establish the then-disputed existence of primitive lime-stone.

These doctrines it is unnecessary to dis-

[a] Journal de Physique, vol. xxxix. p. 374.
[b] L'Encyl. Geographie Physique, vol. i. p. 96.
[c] Journal de Physique, vol. xxxix.

cuss now, as they have no longer any adherents.

As far as our present experience reaches, granite and gneiss seem to belong, peculiarly, though not exclusively, to the more ancient rocks: chalk, clay, sand, marl, loam, rock-salt, to the more modern. Greywacke, sandstone, clay-slate, quartz-rock, sienite, porphyry, greenstone, basalt, serpentine, compact feldspar, seem common to both. In general, the younger rocks exhibit more abraded fragments than the others, more bituminous and saline matter, more organic remains.

2. ON THE STRUCTURE OF ROCKS.

It has been thought that the primitive rocks were formed by chemical, the flötz by mechanical action; and that, in transition rocks, the two actions were combined.

Of these three opinions, the last, though attacked in the Edinburgh[a] Review, is

[a] Ed. Review, Vol. ii. p. 343.

perhaps the only one, which is well founded.

La Metherie [a] observes, that, during the crystallization of primitive rocks, the earths were not all dissolved, and could not all crystallize; for in these rocks we often find a quantity of argillaceous matter in an earthy state. Werner speaks of gneiss containing fragments of granite; and Saussure has shown that brecchias prevail in rocks of every age. Mr. Playfair [b] quotes several instances of arenaceous rocks inter-stratified with rocks decidedly primitive; and greywacke is now very generally admitted into the list of primitive formations.

It has been proposed to substitute for the terms primitive and secondary rocks, crystalline [c], and deposititious; but, unfortunately, rock salt is as crystalline as clay slate,

[a] Theorie de la Terre, vol. v. p. 25.

[b] Illustrations. See also on this subject Dr. MacCulloch's able account of quartz rock in Geolog. Trans. vol. ii. & iv.

[c] M'Lure, Journal de Physique, vol. xii. p. 145.

sulphur as porphyry, the Fontainbleau sandstone and burrstone as greywacke, gypsum as serpentine. Mechanical action seems to have commenced at a very early period, and chemical to have continued up to the formation of the latest strata.

Dolomieu[a] was, I believe, the first who made the conglomerate, or old red sandstone, the line of demarcation between the primitive rocks and the secondary.

The structure of rocks changes, by almost imperceptible gradation, from granular to compact, from compact to porphyritic, from porphyritic to amygdaloidal, &c. In general, however, the crystalline rocks may be said to be the oldest; the sandy, marly, clayey, the newest.

The granular varieties of limestone are, for the most part, older than the compact, and the compact older than the earthy.

Slate occurs in all formations; but the more perfect varieties seem confined to the primitive and transition rocks.

[a] Journal de Physique, vol. xxxix. p. 390.

3. ON THE SPECIFIC GRAVITY OF ROCKS.

It was thought, during the infancy of geological science, that the order of succession in rocks was that of their specific gravities.[a] Even Woodward, with all his experience, fell into this error. Mr. Hawksbee exposed it at the Royal Society, by simply exhibiting the section of a coal mine.

Considered on the great scale, however, this hypothesis is not, perhaps, altogether erroneous. Generally speaking, the primitive rocks are of greater specific gravity than the secondary; and it appears from the experiments of Cavendish and Maskelyne, that the density of the superficial parts of the globe is less than that of its interior.

4. ON THE CONSOLIDATION OF ROCKS.

Nothing is more common, among the newer rocks, than the alternation of

[a] Varenius lib. i. cap. 7. propos. 7. Hawksbee's Experim. p. 317. Luidii Lythophil. p. 110.

consolidated beds with beds not consolidated.

On the other hand, all the older beds, or nearly all, are consolidated. The fuller's earth found at Rosswein in Upper Saxony, and a similar bed found on the Old Man mountain, at Coniston, occur to me as exceptions to the rule; but, in general, the old red sandstone may be considered the earliest formation, which appears unconsolidated.

As a reason for admitting the igneous origin of trap rocks, it has been[a] said, that, "of all other formations, the degree of "consolidation decreases together with its "age, their texture passing from crystal-"line through the several gradations of sub-"crystalline, compact, coarse, and lastly "earthy, while in the trap formation, even "where it rests on chalk, the crystalline "texture of the oldest rocks frequently "recurs."

I suspect that this distinction is not warranted by fact, and that trap rocks are, in

[a] Geological Transactions, vol. iii. p. 208.

regard to consolidation, analogous to all others; at least, I am not aware, that the successive beds of any formation, which have fallen within the limited scope of my experience, present that regular increase of consolidation, which, with a single exception, is here attributed to all.

5. ON THE STRATIFICATION OF ROCKS.

The Huttonians distinguish carefully between stratified rocks and unstratified. The former, according to them, have been deposited by water, and merely hardened by Plutonic heat; whereas the latter have been thrown up in a melted state from beneath, and forcibly injected amid the pre-existing strata. It is a fatal objection to this hypothesis, that consolidated beds often alternate with unconsolidated, stratified with unstratified.

How far the opinion, which the Huttonians entertain, on the origin of the unstratified rocks, derives support from the phenomena of granitic or basaltic dykes, this is not the place to enquire. I must

confine myself, at present, to an examination of arguments, which they deduce from the nature of the beds themselves. Now what are those arguments? "that the "rocks in question are penetrated by pyrites "—that they contain fragments—that "the beds contiguous are sometimes bent, "disturbed or indurated—that the strata "above them are sometimes similar to "those beneath." Let us grant all this: does the conclusion follow from the premises? or is there any one property, among those here attributed to the unstratified rocks, which may not, equally, be found among rocks that are stratified?

On the other hand, the connection which subsists between beds of granite and gneiss, greenstone and compact feldspar, trap-tufa and clay, toadstone and cornstone, is too intimate to be considered only accidental.

At le Gros Cattel, near Cherbourg, a large-grained granite, consisting of flesh-coloured feldspar, greyish-blue quartz, and black mica, with some tourmalin, cor-

responding, in its general aspect, with the granite of Galway, is intersected, in different directions, by veins of milk-white or blueish quartz, having the gelatinous look of gypsum. These veins vary in breadth from an inch to a foot, and lose themselves, before they have run to any considerable distance. The granite continues, uninterruptedly, till you have passed the eastern promontory of a small cove, called le Poulet, where it is broken off, a few crags still appearing, however, about the middle of the cove. The easternmost of these is made up of the same ingredients as the granite abovementioned; but the feldspar is paler, and the texture of the rock slaty. It appears to dip beneath the granite, and to rest upon killas. At the western promontory, the killas, like the granite, is traversed by numerous veins of blue quartz, which, in the more contorted beds, occurs, also, as a constituent part forming stripes.

I consider the prevalence of this blue gelatinous quartz, in the killas, as well as the granite, though separated from each

other by a bed of gneiss, a strong reason for believing, that these three rocks were formed at nearly the same epoch, and in the same manner.

The dip of the killas is equally adverse to the Huttonian hypothesis. If the granite had, naturally, no connection with its adjacent rocks, but was thrown up, accidentally, in the midst of them, the strata of killas should have dipped the contrary way.

6. ON THE POSTURE OF ROCKS IN REGARD TO THE HORIZON.

Vertical, and highly inclined rocks are reputed older than those which are horizontal.

"Next in the order of time to the consolidation of the primary strata," says Professor Playfair[a], "we must place their "elevation, when, from being horizontal, "and at the bottom of the sea, they were "broken, set on edge, and raised to the "surface: it is even probable, that to

[a] Illustrations, p. 123.

" this succeeded a depression of the same " strata, and a second elevation; so that " they have twice visited the superior, and " twice, the inferior regions. During the " second immersion, were formed, first, the " great bodies of puddingstone, that, in so " many instances, lie immediately above " them, and, next, were deposited the " strata, that are strictly denominated " secondary."

M. Omalius d'Halloy[a] represents the coal measures, and all the strata beneath, to be inclined; the red ground, and all the strata above, to be horizontal. The inclined beds of a mineral basin are, always, older, he says, than those beds which are parallel to the horizon.

I have shown, in a former essay, that every species of rock assumes, occasionally, every posture; hence, the inclination of rocks forms no evidence as to their antiquity. The observations, which I have made, since that essay was written, confirm me in the opinion I then entertained, that

[a] Journal des Mines, tom. xxiv. p. 154.

the extreme difficulty of distinguishing planes of stratification from planes of cleavage, in the slate rocks of inland districts, where small sections, only, are exposed to view, induce us, frequently, to suppose beds vertical, or highly inclined, which are, in point of fact, nearly horizontal.

Ramond [a] assures us, that it is rare to find, in the Pyrenees, at the base of the mountains, or at their summit, in the centre of the chain, or at its extremity, any secondary rock, whose strata form with the horizon an angle of less than 45°.

7. ON THE POSTURE OF ROCKS RELATIVELY TO ONE ANOTHER.

It is often, supposed, that unconformity of posture, in two adjoining beds, proves them to have been formed at different æras. This doctrine I consider erroneous for the following reasons:

1. Sienite, porphyry, basalt, all those rocks, for the decyphering of which so

[a] Journal des Mines, vol. xii. p. 88.

many deluges have been set in motion, occur, indeed, sometimes, in an unconformable, but, often, in a conformable position.

Of the conformable stratification of sienite and porphyry, Professor Raumer has given us a striking instance in the neighbourhood of Freyberg. Heim, I think, has noticed another in the forest of Thuringia.

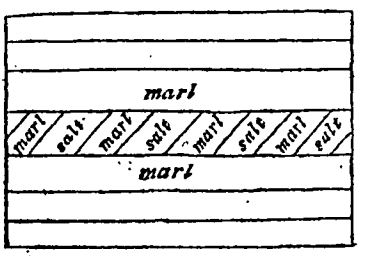
The basaltic rocks of Antrim are conformable to the beds, on which they repose.

2. Of rocks the most intimately connected, many occur, almost always, in an unconformable posture. Gneiss or mica slate is, often, unconformable to granite; greenstone slate to greenstone. What the Wernerians call unconformable and overlying stratification, is, often, only the incursion of unstratified or clotted masses, in masses regularly disposed.

3. Different strata of the same bed are, often, unconformable to each other. Witness those of red sandstone, of Pennant-stone in the forest of Dean, of chalk at

Handfast point; or the laminæ unconformable to the strata, as at Swanwick, Mells, Hedington near Oxford, Anthony-hill near Bath.

The rock salt of Bocknia is said to lie as represented in the following diagram.



4. The same rocks will occur in different parts of their course, both in a conformable, and in an unconformable position.

Dr. MacCulloch has remarked that trap will sometimes appear in the form of a bed running parallel to the adjacent strata, and then suddenly rise through them in the form of a dyke. Similar phænomena, though on a smaller scale, are not unusually

afforded by quartz, amid beds of primitive slate.

The transition and flötz rocks, which, according to a writer in the Transactions of the Royal Society of Edinburgh, are never conformable to each other, are, nevertheless, so strictly conformable along the frontier of Wales, at least to my eyes, that, after repeated examination, I am still unable to determine where the one formation ends, and the other begins.

The planes of mountain limestone, at Ingleton, cover the edges of greywacke slate, though, at Orton, these two rocks are conformable, and graduate into one another.

In some situations unconformity of posture, far from proving that the strata, in which it is observed, were formed at different æras, tends rather to prove that these strata were formed simultaneously. It is scarcely possible to imagine how the primitive limestone of Conemara can have been formed at a different period from that which gave birth to the rocks with which

it is associated; though its position in regard to them is the most eccentric that can be conceived. I feel no less persuaded that the slate and quartz, at Ilfracombe, are contemporaneous, though their respective strata appear to meet nearly at right angles.

At Port Vieil[a], in the Pyrenees, the limestone makes its way through grit-stone; and at Tuccaroy, vertical beds of this last rock are traversed by horizontal beds of limestone: yet, says the author to whom we are indebted for a description of that district, "it would be wrong to "suppose the one merely deposited on "the other. Both were deposited at the "same moment, and from the same pre-"cipitate: the two substances are blended "together along the line of junction, and "the intermixture continues to a certain "distance on each side of it."

In all these cases unconformity appears to have been occasioned by the disturbance

[a] Picot de la Peyrouse, Journal des Mines, vol. vii. p. 55.

which one of the substances sustained from the deposition or precipitation of the other.

8. ON THE DIP AND DIRECTION OF ROCKS.

The difficulty of determining these in primitive rocks has been already stated. Humboldt has hazarded an opinion that the primitive[a] rocks, both in Europe and America, run N.E. and S.W., forming with the meridian an angle of 50°, and dip to N.W., at an angle varying from 60° to 80°.

Dolomieu[b], however, did not find this to be the case in the Alps, nor Cordier[c], in the Pyrenees; and succeeding[d] travellers in other parts have multiplied exceptions to the rule till it has become useless.

The secondary rocks in the[e] Pyrenees

[a] Journal de Physique, vol. liii. p. 46.
[b] Ibid. vol. xlvi. p. 423.
[c] Journal des Mines, vol. xvi. p. 252 and 281.
[d] See Illustrations of the Huttonian Theory, p. 228.
[e] Journal des Mines, vol. xii. p. 88.

agree in direction with the primitive; the same conformity, if I am not mistaken, prevails also in England.

9. ON THE ALTITUDE OF ROCKS.

According to the Wernerian theory, a succession of rocks is always accompanied by a diminution of level, the waters from which they were deposited having subsided progressively during the period of their formation. The outgoings of the newer strata, therefore, are lower than the outgoings of the older, from granite downwards to the alluvial depositions; the trap rocks, however, being on this, as on every other occasion, a privileged order, not amenable to the laws imposed upon the rest of created matter.

With this one exception, however, we ought to be able to determine the relative age of rocks, by comparing their height.

La Metherie[a], who adopted this doctrine without sufficient examination, appears a

[a] Theorie de la Terre, vol. iv. p. 371.

good deal embarrassed in his attempt to sustain it. His assertion, that the granite of the Pyrenees is higher than the limestone, is followed by an admission that the limestone also is very high, sometimes higher than the granite. He accounts for this by assuming, that the granite is the more perishable of the two, and by supposing that it must have been the higher formerly, though the lower now.

The secondary ridge of the Jura is higher than the primitive ridges of the Vosges and Bretagny.

Mont Blanc*, the highest mountain in Europe, is said not to consist of granite. Be this as it may, its summit is only 128 feet higher than that of Mont Rosa composed of stratified rocks.

The principal heights of the Apennines are of secondary limestone.

In the British islands the principal eminences, Ben Nevis, Snowdon, the rocks of Killarney, and the mountains of Cumberland, are composed either of porphyry

* Saussure's Voyages, § 2135. Playfair's Illustr. p. 200.

slate and compact feldspar, or of granular quartz, or of slate marked with fossil impressions.

The Ocrynian and Charnwood hills, composed of granite or sienite, are lower than the Pennine or central hills, composed of secondary limestone and coal measures.

MacClure affirms, that there is no rule, as to the height of the several primitive rocks in North America.

Near Huanco [a], in Peru, coal measures attain the height of 14,700 feet, the highest granite in that country being 11,500 feet high. At the Magdalen river, north of Quito [b], coal occurs at an elevation of 12,000 feet above the level of the sea.

Mount Ararat, Etna, the peak of Teneriffe, and the greatest eminences of the Andes, are volcanic.

La Metherie [c] is prodigal of reasons why gneiss should be found at great elevations,

[a] See Andes, in Supplement to Encycl. Brit.
[b] Journal de Physique, vol. xxxviii. p. 30.
[c] Theorie de la Terre, vol. v. p. 11.

as if not aware, that it is also found below the level of the sea.

10. ON THE METALS CONTAINED IN ROCKS.

The German miners divide rocks into flötz-gebirge, where the ore occurs in beds, and gang-gebirge, where it occurs in veins.

With the exception of pyrites, metallic ores are rare in the newer rocks. Galena and blend in small quantity have been found, however, in the coral rag of Yorkshire; and galena, calamine, and iron ore, are raised in Silesia from a rock more modern than lias.

Tin, molybdæna, tungsten, wolfram, are said to be confined to the oldest rocks. Uranium and titanium are nearly contemporary with these.

Dolomieu denies that rocks can be properly divided into the metalliferous and non-metalliferous; none, he says, are necessarily destitute of ores, but, in some mountain-chains, the fissures are too few in number, or too inconsiderable in extent, to

allow the rocks to be metalliferous, be their substance what it may.

11. ON THE FOSSIL CONTENTS OF ROCKS.

It is said in the Wernerian theory[*]; that there is a relation between the nature of fossils, and the age of the rock which contains them; that zoophytes, the lowest and most imperfect class of animals, were first formed; then, shell fish, and marine plants, of a nature unknown to the present world; afterwards, the same genera of animals as those we are acquainted with; and, still later, the same species. Land-plants are said to be more recent than any of these, and land-animals more recent still.

Whether Werner derived this idea from the study of nature, or from the perusal of

[*] See Von Buch's Norway, translated by Black, p. 47, and the note by Professor Jameson. Also in Transactions of the Royal Academy of Berlin, a Memoir by Von Buch, "Ueber das Fortschreiten der Bildungen in der Natur."

Telliamed, who imagined, that birds and beasts sprung originally from the sea, and that men and women themselves were only an improved breed of fishes, I know not; but there seems as little reason to believe, that a progressive amelioration took place in the nature of the beings called into existence previously to the deluge, as that a corresponding degeneracy can be attributed, with any degree of justice, to those of succeeding ages.

It is not correct to say, that zoophytes were the first born of animals: for the genealogy of the nautilus is quite as long as that of the madreporean polypus.

It is not always, nor, perhaps, generally, true, that the fossils of the older rocks are more unlike the productions of the present world, than the fossils of the newer. The fishes, whose forms are impressed on the bituminous marl-slate of Germany, are not more strange to us than those found in the lias, the Portland stone, the Purbeck stone, the chalk, or the rock of Monte Bolca, and Oeningen; nor the cacti, in coal-mines, than the fruits of Sheppy Island, imbedded

in London clay; nor the ancient corals of Derbyshire than the more modern ones of Berks and Wiltshire: nor the nautili of transition countries, than the ammonites, belemnites, hippurites, scaphites, baculites, and nummulites, which occur in rocks of a much later æra. Among the larger animals, one of the oldest, we are acquainted with, is the crocodile: now the fossil crocodile is certainly not more unlike an animal of the present world, than the megatherium, the palaiotherium, the anoplotherium, which are all found in rocks comparatively modern, or even than the mastodon, interred in alluvial soil.

It is said to be certain, that oviparous quadrupeds[a] had the start of viviparous. The latter have been found, hitherto, in regular strata, at Montmartre, and one or two other places; but we cannot suppose, that all the viviparous animals, which existed before the deluge, were interred there only; many must have existed in

[a] Cuvier, Discours Preliminaire, p. 68.

other districts, though their bones have not yet been discovered, or recognized, or perhaps have perished; and who can venture to assure us, that the strata, in which they were enveloped, are not of more ancient date, than those which belong to the basin of Paris?

The occurrence[a] of wood in flötz-trap has been adduced in proof of the newness of that formation; but wood is found in every rock from the lias upwards: it is found also in the coal-measures; the immense tree preserved in the Museum at Dresden, is said to have been imbedded in porphyry.

The occurrence of deer's horns[b] would furnish a more convincing argument, if these horns are really found in trap.

An opinion has for some time past been entertained in this country, that every rock has its own fossils.

"Quarries of different stone," says Lis-

[a] Jameson's Mineralogy, vol. iii. p. 85. [b] Ibid.

ter[a], "yield quite different sorts, or spe-
"cies, of shells; the cockle-stones of
"the iron-stone quarries of Addertone, in
"Yorkshire, differ from those found in
"the lead mines of the neighbouring
"mountains, and both these from the
"cockle quarry of Wansford bridge, in
"Northamptonshire; and all three, from
"those to be found in the quarries about
"Gunthorpe and Beauvoir Castle."

The same writer followed the course of the chalk marl over an extensive tract of country by mere attention to its fossils.

Mr. Strange[b] traced the gryphus from the lower part of Monmouthshire and Purton Passage, through Gloucestershire, Worcestershire, Warwickshire, and Leicestershire, occupying in these counties, as in Northamptonshire, the lower parts under the hills.

"The mountains of Glaris," says another author[c], "produce nummulites, ammo-

[a] Philosophical Transactions, No. lxxvi.
[b] Archæologia, vol. vi. p. 36. for 1782.
[c] Journal de Physique, Introduction, vol. ii. p. 606.

" nites, crook-beaked oysters, and sea-
" shells of distant or unknown parts,
" imbedded in rocks of coarse limestone;
" whereas the adjacent mountain of Blut-
" tenberg, being composed of black slate,
" affords only the skeletons of fish."

After pointing out various circumstances by which different strata may be discriminated, Mr. Calcot[a] says, " they are dis-
" tinguishable, still more remarkably, by
" the fossil bodies they contain, one layer
" abounding with one species of shells,
" another with a different; another layer
" containing bones and teeth of fishes,
" another corals of various kinds;" &c.

Deluc[b] observes that " the fossils of chalk
" are different from those of other beds, and
" that gypsum also has its peculiar fossils."

Mr. Martin[c] assures us that " in Derby-
" shire the shells, corals, &c. which abound
" in the first limestone strata, are by no
" means frequent in the second, nor are the

[a] Calcot on the Deluge, p. 161.

[b] Journal de Physique for 1791, vol. xxxviii. p. 175. and p. 181.

[c] Tilloch's Magazine for 1811.

" petrifactions of the second limestone com-
" mon to the first or third, though all these
" strata are evidently constituent parts of the
" same formation. In the coal soils of that
" county, the constituent strata of gritstone,
" ironstone, shale, &c. may all be charac-
" terized," he thinks, " by their respective
" vegetal fossils."

Mr. Smith is well known to have embraced this idea at an early period, and, in a table attached to his Geological Map of England, has specified a variety of fossils, by which the strata of England may, in his opinion, be identified.

That the fossils contained in secondary strata, are, of all empyrical and accidental characters, the most useful, in enabling us to follow the direction of these strata, no one can dispute; but their utility has been greatly over-rated. Those who maintain that formations are universal, and produce every where the same fossils, must maintain, that these fossils are also universal; in other words, that every part of the earth has been peopled, at the same period, by

the same animals, which, from the nature of many of those animals, is absurd: for if, in the pre-existing world, as in the present, different animals inhabited different countries, then are fossils not universal; but each class confined to an area of greater or less extent, and consequently, within and without that area, the fossils of the same formation will not be the same.

In South America belemnites and ammonites are entirely unknown.

The belemnite is said to be characteristic of the chalk of France; in the chalk of Ireland it is common; in that of England rare. Many differences are observable between the fossils of the Kentish Downs and those of Wiltshire. The fossils of Cherryhinton, in Cambridgeshire, differ from both. The plants impressed on the coal-slates of Somersetshire are very unlike those found under similar circumstances in Yorkshire. The rock at Maestricht is said to belong to the chalk formation, yet its fossils are peculiar, or nearly so, to that spot. Of the five hundred varieties of fruit found at the Isle of Sheppey, scarcely one

has been discovered in any other portion of the London-clay. The Tisbury bed contains Coral at Tisbury only. Of the fossils which have been described as belonging to the lower marine formation in France, very few have been recognized in England.

If fossils were distinctive of the beds in which they occur, they should severally occur in one bed only; now what fossil is there, the range of which is so circumscribed? the Palaiotherium and a few others: but the bones of the Crocodile appear in lias, in Stonesfield-slate, in cornbrash, in Oxford-clay, in Kimmeridge-clay, in Portland-stone, in Tetsworth-clay, in green sand, in the Maestrich rock, in London-clay. The Crab, or part of that animal has been observed in mountain-limestone, in Stonesfield-slate, in iron-sand, in green-sand, in chalk, in Folkstone-clay, in London-clay: teeth and palates of Fish, in mountain-limestone, in lias, Bradford-clay, cornbrash, Purbeck-stone, iron-sand, green-sand, chalk, the sand of Reading, the Sheppey-clay. Entomolites, in clay-slate,

transition-limestone, mountain-lime stone, green-sand, chalk. Madrepores in transition-limestone, mountain-limestone, lias, in the oolite of Bath, in that of Oxford, in Stonesfield-slate, green and iron-sand, in the unknown rock of Antigua, in agate. Pentacrini, in the limestone of Benthal-Edge, in lias, inferior oolite, Bath-oolite, Stonesfield-slate, cornbrash, Kimmeridge-clay, chalk. Patellæ in the Walton beds, Bath-stone, transition-limestone.[a] Echini in mountain-limestone, red-marl, lias, Bath-stone, Stonesfield-slate, iron-sand, green sand, chalk, flint, &c.

Why should I extend this catalogue by introducing oysters, ammonites[b], anomiæ, common to almost all formations? Enough has been said to shew, that, as in different parts of the same bed we find different fossils, so also in different beds we find the same fossils.

[a] Von Buch's Norway, p. 420. of the Translation.

[b] At Chamont, departement de l'Oise, ammonites are found even above the Calcaire grossier.

Mr. Farey admits[a], that different rocks produce fossils of the same genera, but thinks the species characteristic; if that opinion be correct, it follows, that, as often as a new rock was deposited, all the then-existing species of shell-fish were destroyed and new species created, a circumstance by no means probable; let us look to the fact.

The Grignon-bed affords at least eight species of patella and tellina, ten of venericardia and turritella, twelve of melania and ampullaria, fifteen of mitra, bulimus, and cytharea, eighteen of ostrea and murex, twenty-five of pleurotoma, thirty-three of fusus, sixty of cerithium: it may afford still more, but these have been described.

Is the same species of fossil confined to only one rock? sometimes it is; nay more; it is confined to a small portion of that rock, perhaps to a single quarry; but more frequently the same species occurs in rocks produced at very different æras:

[a] Tilloch's Magazine, vol. xxxix. p. 89.

thus, the ammonites jugosus is found in oolite and coal shale; the modiola depressa in London-clay and lias; the perna aviculoides in the clay of Shot over and the aluminous rock of Whitby; the terebratula lateralis in the fuller's-earth of the Cotswold, and mountain lime-stone.

If the genera and species of fossils do not furnish us with the means of determining the relative age of rocks, it may be supposed, that the existence, or non-existence of fossils, prove these rocks to have been severally formed at an earlier or later period than that in which organic beings were formed. The grand division of rocks into primary and secondary[a], is founded chiefly upon this distinction.

Even here however, difficulties present themselves.

The siliceous-limestone and millstone-rock of Paris which contain shells, and those which do not contain them, closely

[a] Encycl. vol. lix. p. 323.

resemble each other, not only in mineralogical character, but in position.

The shells on the summit of Snowdon prove that animated beings existed at the birth of the rocks composing that mountain, and we are far from having ascertained that any other rock can boast a higher antiquity. The greenstone of Tobago, which has all the mineralogical characters assigned to primitive greenstone, also contains shells. In the museum of the East India Company is preserved a similar specimen with shells brought from Hindostan.

On the other hand, how many are there of the more modern strata in which no fossils have been discovered! If the absence of fossils does not prove, that gypsum, rock-salt, grey-wether-sand-stone, &c. were formed before the birth of organic matter, how does their absence prove, that granite, sienite, porphyry, &c. were formed before that epoch?

A very slight acquaintance with nature is sufficient to convince us, that the presence or absence of fossils, in a rock,

depends less on the period of its depotion than on the nature of its materials. In the older formations, calcareous beds often contain fossils, while the argillaceous are destitute of them. In Yorkshire and Cumberland, the limestone abound in fossil shells; but the hazels, plates, and toadstones, seldom, if ever, contain them.

Some writers have supposed, that crystallization is unfavorable to the existence, or rather the preservation of organic matter, and others have doubted, whether the presence of organic matter be not fatal to crystallization; but the red-marl is not crystallized, though barren of shells; nor do we discover a more crystalline structure in the varieties of argillaceous-slate in which fossils are wanting, than in those varieties in which fossils abound.

Generally speaking, vegetable remains are most common in argillaceous beds, and animal in calcareous.

The presence of fossils in some strata is certain; their non-existence in others must always be problematical. How rarely, where bones are found in the best preservation, do we find enough of them to form

a complete skeleton! Is it to be supposed that the animals of which these constituted a part, were *monstra per defectum?* Is it not probable, that chalk which contains so many teeth and palates of fish, contains also other parts of the animals to which these teeth and palates belonged?—and, if so, that organic matter exists in many siuations, in which its existence has not been observed or suspected?

ESSAY VII.

ON THE HISTORY OF STRATA, AS DEDUCED FROM THEIR FOSSIL CONTENTS.

THAT fossils are what they appear, and not nature's counterfeits, is a doctrine on which there is no longer any difference of opinion: it is remarkable, however, that, amid the vast number of fossils which have been discovered, there is scarcely one exactly similar to any existing plant or animal. All we can say then of fossil productions is, that they are analogous to recent; but, of analogy there are infinite degrees, some so loose that to discover them is an indication of genius, others so striking that it would be a proof of dullness to overlook them. It is essential, therefore, in reasoning from recent to fossil bodies, that we should be aware of the *degree* of analogy, that we should know what are the fossil individuals

that correspond with recent individuals, of fossil species with recent species, of fossil genera with recent genera; for on the *degree* of analogy depends the degree of evidence.

By neglecting this consideration, by identifying objects which are only analogous, by seizing on resemblances and overlooking distinctions, Naturalists, who, from the extent of information they possessed in their respective departments, might have rendered to geology essential service, have too often endeavoured to foist upon it conclusions the most wild and extravagant that can be imagined. Of an hundred and five different species of fish[a] enumerated as belonging to Monte Bolca, thirty-nine are said to have come from the Asiatic seas, three from the African, eighteen from those of South, eleven from those of North-America. What follows? that the fishes abandoned their native seas to meet at this spot, or that they were transported thither simultaneously over land or through the air? This is not likely. Shall we say then, that the fishes remained true to

[a] Saussure, § 1535.

their respective seas, but that the seas migrated? This is not likely. Two other suppositions remain; one, that Conchology is fallible in its decisions; the other, that the propounder of the doctrine was ill-grounded in Conchology: whether either or both of these suppositions be true, I leave to the judgment of those, whose judgment upon such a point is more valuable than mine.

It has been stated[a], that in every coal-mine the fern of America is blended with the palm of Africa, and the Asiatic bamboo. What follows? Did Asia, Africa, and America travel to England, or England to Asia, Africa, and America? How happens it that one and the same deposition went on quietly and uninterruptedly in spite of the locomotion? How happens it that our floating and fortunate island, enjoying at the same moment the advantage of opposite climates, produced plants both of tropical and polar regions? If these things are incredible, there is reason to apprehend that we may be misled, as well as instructed, by Botanists.

[a] Dolomieu, Journal de Physique, vol. xxxix. p. 399. See also Playfair's Illustrations, p. 178.

In their most perfect state, all the sciences would be strictly in unison. Nothing can be true in natural history which is impossible in natural philosophy. It is not surprising, therefore, that modern observers should find the observations of their predecessors inaccurate, when opposed to the conclusions of every other science. Brocchi and Reniere think that many of the shells, found at the foot of the Apennines, which have been deemed peculiar to the East Indies, Africa, America, and different seas in Europe, now exist in the Adriatic. Poli has found, in the bay of Naples, many shells, and Maratti, many zoophytes and madrepores, which are usually considered to be the productions only of distant seas. These discoveries, however, do not take away from the marvellous; they only keep it in the back-ground. The resemblance between the Sub-Appennine fossils and the recent shells of the Mediterranean and Adriatic, if established, is a coincidence, extraordinary indeed, but fortuitous; for it is evident, that these fossils were interred at the period in which strata were deposited,

at a period when the relative positions of land and sea were different from what they are at present; when perhaps [a] the Adriatic and Mediterranean were not in existence.

The alternation and occasional intermixture of sea-shells with those of fresh-water, is common to all the secondary strata, and not unknown in the transition. The greywacke-slate of the Harz contains encrini and reeds. Sea-shells, accompanied by impressions of fern, are observable in the dunstone of Ludlow and South Wales. Coal-shales and nodules of iron-stone exhibiting casts of fresh-water muscles, are often interposed between the coralline limestones of the northern counties. The monitor, which occurs in the copper-slate of Thuringia, is associated with fresh-water fishes and marine shells. The lias affords ferns, nautili, and crocodiles; the slate of Stonesfield, remains of birds, beasts, and

[a] Vide supra, Essay, 2.

marine animals. The Petworth and Purbeck marbles, containing a species of paludina, alternate with beds of sand-stone, charged with marine univalves and bivalves; fruit and leaves are found with marine exuviæ in chalk. The clay at Sheppy Island, abounding in sea-shells, is reported to yield no less than five hundred varieties of fossil fruit; fresh-water shells intermixed with marine have been observed, also, at Barton Cliff, at Brentford, and other spots near London in the same bed. The alternation of fresh and salt-water productions at Headen in the Isle of Wight, and in the corresponding strata of the basin of Paris, is notorious. At Guespelle, at Pierre-Laie, at Grignon, &c. [a] sea-shells are intermixed with fluviatile. At Montmartre [b] the gypsum exhibits animals of land, air, and water; the middle beds [c] of that rock contain fresh-water shells; the upper and lower, marine.

[a] Journal de Physique, vol. lxxvii. p. 362.
[b] Ibid. vol. lxxi. p. 391.
[c] Ibid. vol. lxxvii. p. 365.

In the area included by a line drawn from Mayence through Frankfort and through Hockheim back to Mayence similar alternations are observed of fresh and salt-water productions. At Monte Bolca, Pappenheim, and Oeningen, impressions of fishes occur with land plants, and at Monte Pulgnasco[a], the bones of the elephant and rhinoceros are mingled with those of cetaceous animals.

How these extraordinary alternations and intermixtures are to be accounted for, and whether they are attributable, in all cases, to one and the same cause, it is difficult even to conjecture. In the basins of Paris and the Isle of Wight, the only districts in which the subject has been properly investigated, it has been thought the most easy method of solving the problem to imagine alternate inroads and retreats of the sea, coupled with the occasional existence of fresh-water lakes.

This hypothesis, however, is open, I

[a] Journal de Physique, vol. xxxix. p. 399. Vol. lxvi. p. 195. Vol. lxvii. p. 81. Vol. lxxx. p. 50.

conceive, to insurmountable objections. The supposed fresh and salt-water beds, are identical in substance, and comformable in position; there is no mineralogical difference between the beds of gypsum, which contain cerithiæ, and those which contain cyclostomata, lymnæœ and planorbes; between the marine-lime-stone and the fresh-water limestone, the marine-grit and the fresh-water grit. Is it possible, that, the depositing menstruum having changed, the matter deposited should not have changed also? or that, a sea having retired before a lake, or a lake having been overwhelmed by a sea, no trace of such catastrophe should be visible any-where on the then, and still-unconsolidated materials, which furnished the scene of action?

Is the distinction between fresh-water and salt-water shells so strongly marked that they cannot be confounded? The common test is the thickness of the shell, but sea-shells are by no means uniformly thick, as we see in the oyster, &c., nor those of lakes and rivers uniformly thin. In a series of bulla, patella, pecten, pinna,

argonauta, &c., it is easy to find shells as delicate and fragile, as those which are usually contained in rivers or lakes.

I am not aware of any other character, by which a naturalist can distinguish *a priori* a fresh-water shell from one inhabiting the sea.

Shells have been divided[a] into littoral and pelagian, but it is difficult to say in what depth of water any fossil was imbedded. Pentacrini, ammonites, oysters, crocodiles, together with a quantity of wood, are found in the same rock. Was the sea, which deposited that rock, deep and shallow at the same moment?

It seems admitted by all naturalists who have considered the subject that fossil productions, whether vegetable or animal, found in northern latitudes, have a general resemblance, a family likeness to vegetables

[a] Rouelle and Lavoisiere, Journal de Physique, vol. lxxv. p. 446.

and animals, found recent in southern latitudes; but that the converse of this is not true.

The elephant of the Lena river presented an entire skeleton covered with skin and hair; the character of the hair by no means justifies the common opinion that this animal was the native of a southern climate.

Its remarkable preservation is owing probably to the ice by which it was surrounded; and if so, the ice must have formed nearly at the same time at which the elephant died; thus we obtain a clue to the temperature which then prevailed in that part of the world, and a proof that the same degree of cold has prevailed there ever since. These facts are of great importance to the speculative geologist, but, as yet, thoroughly inexplicable, and it is better to avow our ignorance than to display it.

ESSAY VIII.

ON MINERAL VEINS.

Dr. Kidd observed one morning a narrow crevice running along his path. A few days afterwards he found this crevice widened, and, opening into it on either side, many lateral crevices, which at the further extremity became gradually narrower till they were lost.

It is probable that fissures in general have been produced, as these undoubtedly were, by shrinking, and are coeval with the consolidation of strata.

A crystal of calcareous spar will break most readily in laminæ. A broken crystal of quartz will be generally speaking conchoidal, and of corundum ragged; so each uncrystallized body has a more or less determinate fracture. Blocks of granite

and limestone assume one figure; of basalt, another; of slate, a third: they all break in that direction in which the cohesion between their several particles is least: the form of the block depends therefore on the nature of the substance, and the form of the fissure depends on the form of the block.

According to the laws by which the cohesion of its particles is regulated, a stratum in shrinking will divide into large blocks or small. The pedestal of the statue erected to Peter the First was hewn out of a block which weighed 1500 tons. How different its dimensions to those of the fragments which we see re-united in a specimen of ruin-marble from Florence, or jasper from Bohemia!

Fissures may also be produced or enlarged by the contraction of an adjoining mass, by the shock of an earthquake, or by failure of support, owing to the erosion of subterranean waters.

The fissures in Septaria can have been occasioned only by contraction, but con-

traction hardly occasioned the fissure in Yorkshire, which extends from the eastern moorlands to the western, and disturbs indiscriminately in its progress all the beds which are interposed between the oölite series and that of the mountain limestone.

In the north of England, both varieties of fissure expand in calcareous beds, contract in siliceous, and almost close in argillaceous; but the rule does not hold good universally. The rocks at Adersbach, in Bohemia furnish a convincing proof, that fissures of sandstone may be as considerable as those of limestone.

The widest vein that occurs to me is in the Isle of Arran; it measures 160 feet across. There is one at Lauterbrun, in Swisserland, which measures 140 feet.

The inclination of fissures is regulated in some degree by the nature of the intersected stratum. In the mining districts of Yorkshire, Cumberland, and Durham, they are said to be nearly vertical in calcareous beds, in argillaceous nearly horizontal, in siliceous oblique.

At Cooper's dyke head, near Alstone, the sun vein cuts the coal-sills, white hazel, and little limestone vertically; it dips four feet in six where it traverses the plate; runs horizontally for five feet along the surface of the great limestone, and then cuts it vertically.

Extensive fissures are for the most part accompanied by a subsidence of the adjacent strata, and, generally speaking, the amount of the subsidence is more or less considerable in proportion to the size of the fissure.

Subsided beds sometimes preserve their parallelism; instances of this may be seen at Fairhead, and on the west of Aust passage, or, on a smaller scale, in specimens of Florence or Cottam marble. More commonly their parallelism is lost.

Where a subsidence has taken place, the strata on the hanging side are said to be lower than those on the lying side; in other words, the subsided strata form the roof of the vein. Exceptions to this rule occur at Westbury Cliff on the Severn, and at Balahulish in Scotland.

Fissures which cut the strata obliquely have been observed to produce more dislocation than those which cut them vertically.

The quantity of dislocation occasioned by a fissure, will differ at different places.

Fracture and subsidence do not necessarily produce fissures. In the collection of Signor Castellini at Schio, a specimen of calcareous slate from Monte Bolca on one side exhibits the impression of a fish's head, on the other side the impression of its tail. In this case, the upper strata have merely slid over the edges of the lower. Of the same nature is the extraordinary slip at Handfast Point in Dorsetshire.

ON MINERAL VEINS.

Veins are chasms filled with mineral matter; if with stony matter, they are often called dykes; if with tin or copper, lodes.

If they intersect the strata they are called rakes; if they lie between them,

pipes, flats, or dilated veins. The latter are comparatively rare.

Where a section passes near the line of junction of two rocks, the surfaces of which are curved or irregular, portions of the one will be seen protruding into the other. Appearances of this kind have frequently been observed at the junction of granit or porphyry with killas, and the protruding portions have been improperly called veins. There are real veins however of both these substances.

A vein that lies between the strata in one place, will often intersect them in another. This has been observed particularly of whin dykes *, but it is no less true in regard to metallic veins.

Pipes have excited most attention in the north of England, where they prevail in the Tyne-bottom-limestone the scar-limestone, and the great limestone of Alstone

* To the examples adduced by Mr. Jameson and Dr. M'Culloch may be here added some remarkable ones at Pallis in the county of Limerick, at Carlingford in the county of Louth, at Scormore in the island of Rum, and along the shore of Ardnamurchan.

Moor; not in the plates or sandstones. At Virgin-mine in Wenzley-Dale, are two pipes, which have been followed to the distance of nearly a mile. Three have been worked at Corser and Tyne-head. At the Old Carr mine at Nenthead, they have been very productive.

At Polgooth* and Carnmeal mines in Cornwall a floor of tin was worked twelve feet in breadth, but without the determinate walls usually observable in regular veins.

Veins differing in their contents often intersect.

Veins agreeing in their contents take different directions in different countries.

In the same country similar veins have often, but not always the same direction. At Schemnitz, the veins are said to run north and south; at Scharfenberg, in Saxony, east and west; at Freyberg, north

* Geol. Trans. vol. ii. p. 129.

and south, or north-east and south-west. In Wicklow, the lead-veins run east and west; in Bretagny, north and south.

It was observed by Owen, as early as the year 1595, that the veins in England run from east to west, and this is still the prevailing opinion.

In Cornwall it is thought, that the tin lodes point rather to the north of east, and the copper-lodes rather to the south; but I believe the deviation rarely amounts to twenty degrees. At Wendron, and at Huel Jubilee near Padstow, are copper-lodes, which, if I am rightly informed, run north and south.

The direction of the principal lead-veins in Cumberland and the adjoining counties, seems also to be east and west, but the smaller veins run in every direction. The most considerable lead-vein known in Devonshire, the Bere-Alston load, runs nearly north and south, as do most of the lead veins worked in Cornwall.

The direction of veins [a] is no where determined by the direction of hills; but the nature of the rocks which compose these hills may have influenced the direction of both. Generally speaking, veins were formed before the hills and valleys which now vary the surface of the earth.

Veins are sometimes composed of one substance only, and that nearly the same chemically speaking, as the rock in which they occur; as calcareous veins in limestone, whin-dykes in whinstone; but their contents are often extremely multifarious. Almost all the simple minerals known, are found in veins occasionally, and the greater number exclusively.

Veins produce different substances in different parts of their course.

The Stephani-lode, at Schemnitz, yields lead and gold at one place, silver at another. At Kremnitz the contents of the main lode

[a] See Essay II.

change from gold and hornstone to clay and pyrites. The Old-Gang affords lead in Swaledale, but at Muker and Middleton Tyas, copper. The vein at Welhope is free from sulphate of barytes at one shaft; at a little distance, sulphate of barytes is so abundant that it measures four feet in width. The Rampgill vein, celebrated for fluor at Allenheads, is destitute of it at Coalcleugh. The Huel-Virgin lode in Cornwall, has been followed to the distance of two miles; but the arseniates of iron and copper are found in a very small portion of it. Plush-copper and uranium do not accompany the Huel-Crebor lode all the way from Tavistock to the Thamar river, but only at Gunnislake.

Changes of this nature are most common where veins pass from one rock into another.

Bergman has noticed this at Kongsberg in Norway, and Picot de la Peyrouse* attributes the irregularities and interruptions of the metallic veins in the Pyrenees to the

* Journal des Mines, vol. vii. p. 5

frequent alternation of the rocks through which they pass. [a]

Calcareous veins are most frequent in the secondary rocks; quarz veins in the primitive.

On the east-side of St. Michael's mount, in Cornwall a vein cuts both the granit and killas; in the granit the substance of the vein is shorl; in the killas, quarz.

Another vein on the same island produces, or does not produce, tin-ore, as it passes through granit or through killas.

At Homebush, near Callington the lode is of tin, where it traverses granit; of copper, where it traverses killas.

At Tresavean, in Cornwall the lode is very poor in killas, but rich in granit. The reverse takes place at Huel Unity.

In the lodes worked in granit, there is in general a greater variety of substances than in those worked in killas; this may easily be verified at Huel Gorland, Huel Damsel, Carrarack, and Gunnislake which are

[a] Trebra has remarked, that less argillaceous strata are fertile of precious metals than granit and porphyry. J. des M. vol. iv. p. 72.

worked in both. The lode at Huel Unity bears fluor, only where it traverses granit.

I have been told by Cornish miners, that the tin is generally better in elvan or porphyry than it is either in granit or in killas.

In the north of England the most valuable mines are all situate in limestone; the hazels are metalliferous in a much smaller degree, and in the plate or beds of indurated clay the veins carry for the most part clay only. If lead has ever been found in plate, it is only where, as at Thorngill and Blagill, the plate varies from its usual character, and passes into chert.

When, in consequence of a fault, limestone and plate face each other, and there is a rider of limestone, the lead generally lies between the rider and the lime-stone, very rarely between the rider and the plate. The richest veins are said to be those of which both cheeks are alike.

The Cornish mines appear to be most

productive at the junction of granit and killas: those of Derbyshire and Flintshire, at the junction of limestone with limestone-shale. Raumer has observed an enrichment of the Silesian veins at the junction of different rocks. Ferber remarks that the mines at Agarth near Belluno, at Feltrino, at Schio in the Vicenza territory are all, like those in the Bannat, situate at the junction of slate and limestone.

From these considerations we might naturally infer that the nature of veins is influenced by that of the rocks they intersect; this however is doubtful, for

1. Rocks, which abound in any given veins in one country, contain no such veins in another. Greenstone-slate, for instance, is metalliferous in Silesia and Sweden, not in Great Britain. About Mohorn in Saxony clay-slate is not metalliferous; yet the mines at Schneeberg are all in clay-slate.

Of the limestone tract in North Wales a very scanty portion only produces lead-ore. The great limestone of

Alston is more metalliferous towards the west than towards the east, and more so near the surface than far beneath it. The upper limestone in Derbyshire is the most metalliferous, though it agrees with those below it, both in chemical and mineralogical character.

2. Similar substances occupy the veins of dissimilar rocks.

A vein consisting of galena, black-blend, arsenical-pyrites, iron-pyrites, copper-pyrites, and a small quantity of brown-spar, occurs at Freyberg in gneiss, near Mohorn in porphyry, near Muntzig in clay-slate. A vein, consisting of galena poor in silver, barytes, and fluor, at Freyberg traverses gneiss, in Derbyshire limestone.

3. Dissimilar substances occupy the veins of the same rock. In Cornwall the veins worked in granit are chiefly of tin and copper ore; in Bretagny and Wicklow, of galena.

The sienit of the Isle of Cyprus affords

copper; that of Hungary, gold and silver; that of Thuringia, iron.

"The metallic ores are almost always associated with vein-stones, and ores of different metals belong to the same vein. Without any change of the stratum, we often find a change in the nature of the vein, either in its longitudinal bearing, as at the Old-Gang which produces lead in Swaledale, but copper at Muker and Middleton Tyas, or in the direction of its descent, as the lodes of Cornwall, in which tin lies over copper or alternates with it. *

4. Substances occurring in veins, are for the most part extremely different, in a chemical point of view, from the rocks traversed by them. Thus, stony bodies are intersected by metallic ores. Fluor and barytes are ordinary constituents of veins, as constituents of rocks unknown. No one can imagine a chemical relationship between granit or killas, and the endless variety of simple minerals found in the veins of Cornwall.

* This happens at Tincroft.

And here I must be permitted to observe, that if it is no longer allowable to believe in the philosopher's stone, neither are we at liberty to believe, as many writers are inclined to do, that mineral veins owe their origin to electricity, galvanism, or some unknown cause similar to these. No analogy will support so wild an hypothesis, as that one, or all of these agents should have converted particular portions of rock not merely into a different rock, but into a variety of spars and ores, differing alike from it, and from one another.

We are warranted then, I think, in concluding, that, if the nature of the rock has any influence on the nature of the veins that traverse it, its direct influence is but extremely feeble. Its indirect influence is more considerable, because on the nature of the rock depends the extent, and, in some degree, the direction of the fissures.

It has been supposed that the toad-stone beds in Derbyshire cut out the metallic veins, and are consequently more modern.

The fact is not true, at least invariably. At the High Rake near Tideswell a con-

siderable vein of lead and spar has been followed through the toad-stone for forty-five fathoms in depth. Lead has been worked in the same situation near Castleton in Derbyshire, at Garrigill Gate in Cumberland, and at Kady in the county of Armagh. [a]

The way-boards which divide the mountain lime-stone into beds, the shale which covers it, the chert imbedded in it, the plate alternating with it, often present to the metallic veins a barrier as formidable as the toad-stone does. In the north of England it is considered an extraordinary circumstance that the lead vein at Thorngill and Blagill penetrated all the "sills and plates" up to the very turf.

On the coast of Fifeshire I have seen a vein traverse the subjacent and superincumbent sand-stone, but not the lime-stone which intervened.

Near High Pike [b] in Cumberland a vein, which continues its course uninterruptedly

[a] Whitehurst Inquiry, p. 264.

[b] Phil. Mag. for Jan. 1816.

through sienit to a distance of three miles, ceases suddenly where it leaves the sienit, and reaches the slate.

At Gersdorf * in Saxony, the veins worked in gneiss do not traverse the superincumbent clay-slate; those worked in gneiss at Nicholasberg in Bohemia do not traverse the superincumbent porphyry.

Veins of asbestus, which abound in the drawing-slate of Switzerland, do not penetrate the lime-stone with which this slate alternates.

Whether in all the instances here adduced the vein has really been cut off I am incompetent to decide. My belief is, that in some cases the interruption is real and complete, and that it is so not only where veins quit one rock to traverse another, but in their passage through the same rock. Instances of this may be seen at Glenrosa in the Isle of Arran, and at Bunessan, in the Isle of Mull. On a smaller scale interrupted veins, both of quartz and lime-stone, are well exposed

* Reichetzer's Geognosie, p. 232.

along the slaty cliffs that project into the sea at Ilfracombe. Need I bring to the recollection of my readers the interrupted vein described by Dr. Mac Culloch, in a mass of lime-stone at Waltham Abbey?

In Derbyshire, it would appear from the observations of Mr. Farey [a], that the smaller veins are effectually stopt by the toad-stone, but from the larger veins a crack or rent generally extends some distance into the toad-stone, both above and below, growing narrower, and often branching into different small cracks or strings as it proceeds.

In interrogating miners on subjects of this nature, it is useful to bear in mind that in their language a vein is said to be cut off, when from a diminution of quantity or deterioration of quality in the ore, it ceases to pay the expense of working. At Schemnitz the Stoplitzhofer-grund is said to cut off all the veins; it only impoverishes them.

If it were true that veins were destroyed, or shifted as often as they came in contact

[a] Survey of Derbyshire, p. 245.

with toad-stone, and that in the latter case the part shifted were of the same dimensions and of the same nature as that not shifted, we might, with some plausibility, refer the shift or destruction to an inroad of the toad-stone between the strata after the veins were formed, but then we must in fairness refer to a similar cause all similar phænomena. It is evident, however, that no inroad of toad-stone can have occasioned a ramification of veins, a reduction of their size, or an alteration in their contents. These are circumstances which admit no rational explanation, either by the volcanic or the plutonic theory: they appear to depend on the extent and direction of the intersecting fissures.

The same reasoning may be applied to veins said to have been shifted by other veins. Subsidences have taken place of veins, as well as of strata, but I am persuaded that many veins are supposed to have been broken, which were never continuous, and many shifted which retain at this day their original position.

To establish the original continuity of veins on the opposite side of a cross-course, it is not sufficient to shew an agreement in one spot; we must shew it in many. If by an imaginary shift of a stratum we can bring together, as at Huel Peevor, in Cornwall, the mouths of several veins, then, indeed, we are justified in supposing that such shift has taken place since the veins were filled; but we are not to conclude, because the ends of a road or river on different sheets of a map would coalesce, that the sheets were intended to be so joined; the valleys of the Lea and the Cray both open into that of the Thames, the one from the north, the other from the south, but it does not follow that they were continuous, till the Thames destroyed their continuity.

Some veins are said to have been impoverished on one side of a cross-course, and enriched on the other. May not the parts impoverished and enriched have been parts, not of the same vein, but of different veins?

At Schemnitz is a vein which bears lead and quartz, till crossed by the Wolfgang lode, after which it is said to bear only clay;

but how is it ascertained that the vein, which bears clay only, is the same as the metalliferous?

In the neighbourhood of Alstone two parallel veins are said to be shifted by a cross-course in opposite directions.

Near Redruth two copper lodes, those of Huel Virgin and Huel Maid, meeting obliquely, are shifted by a cross-course, the one to the left, the other to the right.

Where a lode is really shifted by a cross-course, the latter will often contain portions of the former, and the direction of these indicates the direction in which the lode is shifted.

To identify two lodes in the same mine is often a work of considerable nicety, and yet I have met with practical men, who think that the veins which bear calamine in Mendip are the same as those which bear calcareous iron ore in the forest of Dean; who identify the whin-dykes of the Hebrides with those of Antrim; and recognize in the Isle of Man the same veins which have proved productive in Wicklow and in Swaledale.

That in this country the east and west veins are for the most part shifted by the north and south, is a common opinion among miners both in Cornwall and at Alston Moor. In both districts, however, we meet with numerous exceptions. At Hawkside in Harwood a north and south vein is shifted by one running east and west. The great cross-course in Cornwall, which stretches from the English to the Bristol channel, shifts every thing it meets with, except a small fluchan, by which it is itself shifted. The great copper lode of Cronedale in Devonshire, repeatedly shifted by north and south cross-courses, shifts one of these at Huel Luscombe. A similar circumstance attends the lode at Bere Alston in the same county.

According to Werner, the different substances of which veins are composed appear in determinate order on either side.

Of such arrangement I have seen repeated examples, particularly in whin-dykes,

but the exceptions I believe are so numerous, as to do away the generality of the rule. In the veins which I have had an opportunity of examining in Derbyshire and Cumberland, barytes and calcareous spar change places continually. It is not easy to discover a lode in Cornwall, where tin and copper lie in the orderly manner which Werner described. At Glencloy* in Arran, a vein, of which the centre is whin, has one of its sides composed of brecchia, the other of siliceous sand-stone. At Tormore in the same island, the one side of a dyke is basalt, the other porphyry.

"By all the information I could ever "procure," says Hutchinson, "I cannot "perceive there is any instance of a dis- "position of ore in Hungary, Saxony, "Mexico, Achin, or elsewhere, of which "we have not some example in England, "so that he who is thoroughly informed of

* Jameson's Scottish Islands, p. 27.

" the condition of things under-ground in " this island, is qualified to form a judge- " ment of them all round the globe." [a]

We here recognise the doctrine afterwards promulgated at Freyberg, of vein-formations. According to that doctrine, the materials of veins are diffused as universally as those of strata, and if a lead vein in Derbyshire afford the same vein-stones as a lead-vein in Saxony, a common origin is ascribed to both.

" If," says Humboldt [b], " we had an " accurate account of the four or five thou- " sand veins in New Spain, that are either " now working or have been worked within " the last two centuries, we should, no " doubt, perceive in the contents and struc- " ture of these veins such analogies as " would prove their simultaneous origin. " We should find their contents in part " identical with those of the Saxon and " Hungarian veins."

I am disposed to pay due deference to

[a] Hutchinson's Works, vol. xii. p. 368.

[b] Journal de Physique, vol. lxi. p. 273.

these authorities, but if, as has been shewn, the same vein is not uniform in its products or dimensions to the extent of a few perches or fathoms, surely the resemblance of these products at one spot to the products of another vein at another spot is not sufficient to prove that they agree in their character throughout; nor if their identity were established, should we have reason to ascribe to both a common age or a common origin, unless it be absurd to suppose that similar veins, like similar strata, may have been formed at different æras.

It is remarked by Patrin [a], that a zone of copper, lead, and silver ore stretches nearly in the same latitude from England to the eastern extremity of Asia, and thence to North America. In this zone are comprehended the mines of Ireland, England, France, Germany, Hungary, and Transilvania, the Altai, the banks of the Amour, the shores of Kamschatka, and the blue mountains of America. To establish this

[a] Journal de Physique, tom. xxxviii. p. 299. see also Genetti.

doctrine it would be necessary to prove the non-existence of copper, lead, and silver in other parts of the old world. Were Africa and Asia sufficiently explored, similar zones might probably be drawn in other directions with equal propriety.

The junction of veins with the beds they traverse is often attended with curious circumstances, which it is difficult to account for on chemical principles, though in explaining them it is no less difficult to resort to any other. What is *moor-stone* at a short distance from the lodes, will often become *grauan* in their vicinity, or the grain of the granit will be altered, or it will become [a] slaty; or the feld-spar will change into adularia [b], or one of its three ingredients [c] will disappear, or a fourth be added.

[a] I have seen this on the side of a vein of micaceous iron ore near Irton, in Cumberland.

[b] Goatfield, in Arran.

[c] Aberdeenshire, Wicklow, &c.

Such anomalies are particularly numerous and striking by the side of whin-dykes. Along the line of contact common sandstone is sometimes converted into jasper [a] or lydian-stone; chalk into granular marble [b]; coal into coak or plumbago [c]; clay-slate into hornblend-slate. [d]

The most common effect of whin-dykes, appears to be that of hardening the strata adjoining them, but the effect is by no means constant; at Glencloy in Arran, and at Mr. Kennedy's quarry near Belfast, the sides of the whin-dyke are of clay.

The relative age of veins is a subject on which Werner bestowed considerable attention, but respecting which our knowledge still remains extremely confined. It is reasonable to suppose that the oldest veins are

[a] At the blaue Kuppe at Eschweiler, in the department of Forets; on the north-west side of Stirling Hill, at Portree, in the Isle of Sky, and Salisbury Crags.

[b] Antrim and Rathlin Island. [c] Ayrshire.

[d] Glen Tilt. See Geol. Trans. vol. iii. p. 270.

of a later date than the consolidation of the beds in which they occur, because the fissures which they occupy appear to have been occasioned for the most part by the shrinking of these beds during consolidation. We may fairly conclude also, where different beds are traversed by a vein, that the vein is of posterior date to the most modern of these.

Of two veins that cross each other, the intercepted must be the oldest; we should take care, however, to apply this rule only where the vein is really intercepted. Mr. Playfair tells us that in Cornwall granit veins intersect the metallic, and are remarkable for producing shifts in them: no such instance has come within my observation.

According to Werner[a] veins which have no way-board are nearly contemporaneous with the rock in which they occur, but the value of this remark is done away by another remark of the same author, viz. "that a vein is seldom united to a rock

[a] Werner on Veins, p. 137 of the translation.

"through its whole course; this takes place "only in certain parts." Stone-dykes, I believe, have rarely a way-board; the whin-dyke at Cockfield, which has none, traverses mountain lime-stone and lias; is it contemporaneous with both?[a]

The way-board depends, if I mistake not, much more on the nature of the vein than on the period of its birth.

It is maintained in the Huttonian[b] theory, that metallic veins were not formed till after the secondary strata; the foundation of this doctrine I am at a loss to discover. Tin, molybdœna, tungsten, wolfram, uranium, bismuth, and titanium seem to belong exclusively to the rocks of primitive countries. The successive coats of agate and stalactite are in some measure analogous to veins, and these as well as the veins which we find in septaria, and nodules of argillaceous iron-stone, are evidently the effect of secretion or infiltration.

The Huttonian hypothesis, that veins

[a] Werner on Veins, p. 91 of the translation.

[b] Illustrations, p. 123.

have been filled from beneath, appears to me perfectly gratuitous; and the Wernerian hypothesis, that they have been filled from above, though it derives some support from the circumstance of trees and rounded pebbles having been occasionally found in them, is irreconcileable with the alternate opening and closing of veins which we have shewn to take place not unfrequently on their passing from one rock to another.

FINIS.

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